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FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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THE FRANKLIN INSTITUTE.

Stated Meeting, held November 19, 1902.

Acetylene Stored and Transported in Safety.

BY JOHN S. SEYMOUR,
Formerly United States Commissioner of Patents.

Acetylene gas furnishes a brilliant flame which possesses great lighting power. Since it is about seventeen times as luminous as commercial city gas, and under low pressures is not more dangerous in manipulation, it might probably be used in all commercial gas plants were it not that the waste from leakage would be prohibitive. To light with acetylene, therefore, commercially speaking, calls for a generator of the gas on the spot, or else its transportation from a central station in steel tanks under pressure.

But acetylene under pressure is dangerous, and its use is prohibited alike by common prudence and by the rules of the underwriters.

The safe transportation and storage of acetylene in tanks of special equipment is the subject of the present discourse.

The method of storing acetylene in small bulk was discovered by Claude and Hess, French inventors, who ascertained that 1 volume of acetone, at the temperature of 15° Centigrade, at atmospheric pressure, dissolves 25 volumes of acetylene, and under 12 atmospheres 300 volumes, increasing nearly in proportion to the pressure. They communicated their discovery to the French Academy of Sciences (*Compt. Rend.*, 124, 626) in 1897.

One volume of water dissolves 1 volume of acetylene, turpentine dissolves 2 volumes, amyl alcohol 3·5, chloroform 4, acetic acid 6, alcohol 6, and paraffin 26. Water at 0° Centigrade and 1 atmosphere dissolves of nitrogen 0·02, of oxygen 0·041 volume, carbonic acid 1·79, sulphuretted hydrogen 4·37, sulphurous acid 79·79 volumes, and ammonia 1046·63. Alcohol dissolves more; for example, of carbonic acid, 4·33, whereas water dissolves but 1·79 volumes. For the same gas, the same liquid and the same temperature, the weight of gas absorbed is proportional to the pressure.

Claude and Hess proceeded with their experiments and found that the solubility of acetylene in acetone increases with extraordinary rapidity with the fall of temperature, especially as the point of solidification of the acetylene is approached. At minus 80° Centigrade, at ordinary atmospheric pressure, 1 volume of acetone dissolves more than 2,000 volumes of acetylene, while the solution occupies four to five times the volume of the original acetone. Lewes recites this at page 96.

Acetone, being one of the di-methyl ketones C_3H_6O or $(CH_3)_2CO$, may be derived from secondary propyl alcohol (C_3H_8O) and is a mobile liquid procured on a large scale from the aqueous liquid obtained in the dry distillation of wood, by the destructive distillation of acetates and various organic compounds. It is often prepared by the dry distillation of barium acetate at a moderate heat.

Unlike aldehydes, the ketones do not polymerize, but their most remarkable property is an inclination to condense, that is, two or more molecules join, with the elimination of water, forming a new compound. The boiling point of acetone is 56·3 C. = 133·34 F., and it has a biting taste. It is used in making chloroform and as a solvent for fats, camphor and resins.

Acetone is miscible in all proportions with water, alcohol, ether and many ethereal salts, and can be separated from its aqueous solution by the addition of calcium chloride.

Why acetone dissolves this large quantity of acetylene is a question related to the sum of all the qualities of the two substances. Acetylene, C_2H_2, that is, HC:CH, is produced (1) when an electric arc is formed between carbon points in hydrogen; (2) further by passing the vapor of many carbon compounds, alcohol, ether, methane, ethylene, through red-hot tubes; (3) by the reaction of water upon calcium carbide. It has a molecular weight of 26, a density of 13, specific gravity, according to Bethelot, of ·92, theoretical 89·85. One liter weighs 1·165 grams at 0° C. and 760 millimeters. Its specific heat is 1·26, its heat of combustion from 310,000 to 317,000 calories.

Acetylene condenses at plus 1° C. at a pressure of 48 atmospheres. Edmund Davy found that it required 2½ volumes of oxygen, or approximately 12½ volumes of air, to complete the combustion of 1 volume of acetylene, and that 2 volumes of carbon dioxide and 1 of water vapor were produced. Berthelot states the composition of acetylene as carbon 92·3, hydrogen 7·7, total 100, the ratio of carbon to hydrogen being as 12 to 1.

It is, of all the hydrocarbons, the richest in carbon, and is the only one which contains its own volume of hydrogen without concentration. Thus, C_2H_2 represents 2 volumes as a whole and the H_2 alone represents 2 volumes.

The emphatic illuminating power of acetylene results from its high proportion of carbon, which in suspense in the flame gives it a marvelous brilliancy of great whiteness, in comparison with which the incandescent electric lamp appears dull and yellow. It also results from the high temperature of its combustion. It must be burned in a thin flame under a pressure rather greater than that of illuminating gas, about 4·25 inches of water pressure, in order to secure complete combustion, for otherwise the flame becomes smoky by the very reason of its great richness in carbon.

Donner says, page 169, that methane gives 3·5 carcel hours of light per cubic meter of the gas burned; that the normal gas of the city of Paris gives 9·6, of the city of London 11·5, while of acetylene a cubic meter gives 168 carcel hours of light per cubic meter, sixteen times that of the light of Paris, or, as Vieille found in his photometric tests, twenty times the light of illuminating gas in Paris.

Acetylene evolves little heat, and one can, without inconvenience, pass the hand near the flame. For the same quantity of light emitted, the heat evolved by the combustion of acetylene little exceeds that coming from the incandescent lamp. Acetylene contains proportionately much more glowing carbon in the flame and much less hydrogen, not glowing but of great calorific power, than oil gas. Moreover, in proportion to luminous intensity the quantity of acetylene burned is much less than the quantity of oil gas.

The researches of Messrs. Bertholet and Vieille have shown us that, at atmospheric pressure or under the tension of a few atmospheres, acetylene gas may be handled with safety. Under these conditions it is no more dangerous than illuminating gas.

The theoretical heat of combustion of a cubic meter of acetylene, which weighs 1·2 kilograms, taking the average of five trials, is 14,029. A cubic meter of illuminating gas has a heat of combustion averaging 5,500 calories. That of acetylene is almost two and one-half times higher; but Perrodil adds: "Nevertheless, I say at once that for equal light acetylene develops much less heat."

As we shall see hereafter, unit light by acetylene is produced at a mean expense for one hour of 7 liters when the combustion is well regulated, but 7 liters will give in burning 98 calories. The same light with oil gas is obtained since the discovery of the incandescent mantle with 25 liters, which makes 125 calories. If we place the hand above a little flame of acetylene it seems that it does not give any heat and that only comes from the very small delivery of the tip.

Acetylene is the starting point of all organic chemistry. Beginning with pure carbon, we could succeed in forming and obtaining by a series of reactions an infinite number of organic compounds. By well-known reactions we may derive from acetylene, oxalic acid $C_2H_2O_4$, alcohol C_2H_6O, acetic acid, wood spirits or methylic acid, and the whole fatty series.

We may also form the aromatic series. By heating acetylene to a dull red heat in a curved bell jar placed over mercury, we can produce benzine by the union of three molecules of acetylene C_6H_6, and these in turn may be transformed into nitro-benzine $C_6H_5NO_2$, and into aniline $C_6H_5NH_2$, and thus we may obtain the series of aniline colors.

By heating acetylene still more, we may obtain the condensation of four molecules, or styrolene C_6H_8, which with benzine gives anthracine $C_{14}H_{20}$, and anthracine oxidized gives alizarine $C_{14}H_8O_4$, a beautiful red color identical with that which natural madder produces.

Acetylene may be united directly with the unsaturated hydrocarbons. Perrodil, p. 54.

Nascent hydrogen or hydrogen in the presence of platinum black is united to acetylene to give ethylene.

If in a vase filled with water saturated with chlorine we let a few fragments of calcium carbide fall, we see acetylene evolved which burns in contact with the chlorine. P. 55.

Alcohol was always obtained by the distillation of fermented liquors, wine, beer, cider, etc., which springs from the action of ferments or micro-organisms upon sugared liquors, and which transform, we know not how, certain sugars into carbonic acid and alcohol.

Then follows the process of deriving alcohol from acetylene, but it is costly. P. 58. Sugar may be formed from acetylene. Pp. 58–59.

COMBUSTION OF ACETYLENE.

Acetylene burns in contact with air with a brilliant but smoky flame, giving water and carbonic acid. Two volumes of acetylene will give, with 5 volumes of oxygen, 1 volume of vapor of water and 2 volumes of carbonic acid. They evolve at the same time a quantity of heat equal to 318·1 calories, as follows:

Two molecules of carbon give in burning 24 × 8·8, equal to 193·9 calories. Two molecules of hydrogen give 2 × 34·5, equal 69 calories, making a total of 262·9 calories.

But in burning, the acetylene restores the calories which it dissolved for its formation, to wit, 55 calories, which represents the heat of formation which was absorbed in starting from the elements of amorphous carbon.

Returning to the solution of acetylene in acetone, it is interesting to see the operation taking place.

A glass siphon-bottle containing 820 milliliters was partly filled with 250 milliliters of acetone, filling the bottle about one-third full—the height was marked on the glass. A standard pressure gage was attached to the glass jar and a similar gage to a force pump connected with a reservoir charged with acetylene. Acetylene was pumped into the jar with the valve open in order to let the air pass off. The valve in the jar was then closed, the pumping continued until 3 atmospheres had been pumped in, the bottle being shaken all the time. It was then blown off until acetylene bubbled up from all parts of the liquid, whereupon the pumping was resumed. In twenty minutes the pressure gage showed 10 atmospheres. The acetone rose in the bottle 12 millimeters and the bottle became slightly warm to the touch. Again blowing off the bottle until bubbles came up from the acetone so as to dispose of the air, the manometer went down to 8 atmospheres, and then on closing the valve to the jar the manometer rose to 9·33 atmospheres. The jar with the manometer attached was then connected to a gas meter and 10 burners and a large Bunsen burner, the latter consuming 2 feet an hour, and all were lighted. In ten minutes after the jar was connected to the gas meter and the valve opened, more than 33 liters had passed through the meter. The pressure fell to zero, and all without shaking the jar. On shaking the jar the manometer rose ½ of 1 atmosphere, and at the end of five minutes of shaking 4 more liters came out, making in all 33 liters of acetylene that had been dissolved in ¼ of a liter of acetone at 9·33 atmospheres.

Subtracting from 820 milliliters the 250 milliliters of acetone, we have 570 milliliters as the contents of the jar above the acetone before it was expanded by the acetylene, which, being multiplied by 9·33, gives 5,320 milliliters of compressed gas above the surface of the acetone. Remembering that more than 33 liters of acetylene had passed through the meters and the burners in ten minutes, and subtracting the more than 5 liters from that leaves 28 liters that were dissolved in a few minutes in ¼ of a liter of acetone, or at the rate of 112 volumes at 9·33 atmospheres, or at the rate of 120 volumes at 10 atmospheres. This is about half the absorbent power of the acetone, but the difference is due to the short contact of the gas with its solvent and to the heat due to the compression of the gas and to the chemical action implied by the solution.

The solubility of gases and liquids in water has not been exhaustively examined, and the vast majority of determinations are of but little value owing to neglect of conditions to ensure accurate results; but it is certain that the diminution of volume undergone by the more soluble gases is extremely great and equal to that produced by pressures which are far beyond practical application. Thus Thorpe's Dictionary of Applied Chemistry gives it that a saturated solution of ammonia gas in water contains an amount of gas condensed to such a volume as would, if effected by pressure alone, require over 500 atmospheres, or about 3·5 tons per square inch. Of course, the gas would be liquefied long before this pressure would be reached.

The application of this principle to the storage and transportation of acetylene gas is at a single step to realize all the advantages of impossible pressures in reducing bulk and by the use of only moderate pressures of from 10 to 15 atmospheres.

The gas comes forth readily from the liquid when the pressure is released, and can be utilized by the aid of a reducing valve in the ordinary applications of light. Vieille, of the Council of Public Health and Safety in the Department of the Seine, found and published officially in 1898 that on condition of not exceeding the degree of saturation corresponding to pressures of 10 atmospheres at the ordinary temperature of 15° C. about, the solution of acetylene in acetone constituted an inert liquid, capable of withdrawing the acetylene which it absorbed from all known means of excitation; that is to say, that the liquid neither detonates by shock nor by a fulminate priming.

Much was anticipated from this invention alone, and steel receptacles were made with a diaphragm furnished with a reducing valve at the orifice, on one side of which was to be the acetone and on the other acetylene at about 4·3 inches of water pressure. But the dangers of liquid expansion are encountered on one side, and without the diaphragm the compressed acetylene gas above the liquid remains explosive; yet it is a satisfaction to know that the explosion of this gaseous mass provoked artificially is not propagated to the liquid. In the upper part of the apparatus without a diaphragm, therefore, the same dangers would be present as would be found in a cylinder containing compressed acetylene alone. The fundamental discovery, therefore, of Claude and Hess thereby enormously increasing the capacity of a receptacle by partly filling it with acetone, required to be supplemented by another which would recognize and take care of the difficulty which I have just mentioned; and accordingly, Edmond Fouché, of Paris, equipped a receptacle containing acetone and acetylene with a porous substance, brick for example, of special make, of 80 per cent. porosity, and pierced with holes of about 1 millimeter in diameter, to facilitate the diffusion of the gas.

We have, therefore, the interior of the receptacle converted into interspace, minute communicating cells connected by small perforations, the walls of which are moistened with the contained acetone. This enormous surface of the acetone film gives a better contact with the acetylene as it is pumped in, and greatly facilitates the absorption of the gas. Other substances may be employed in the place of the brick; mineral wool, pumice stone, ceramic materials and carbon are all available. A composition formed of cement and charcoal has been found very light, having a density of 0·3 and a porosity of 0·80, but it is applicable to compressed acetylene without acetone, the liquid being decomposed little by little by the chalk. We have found in this country that asbestos made in disks like the one now shown, encrusted with an application of liquid glass for stability, is most advantageous on account of its lightness, the crust not interfering unfavorably with the absorption. These porous substances have the property of eliminating all danger of accidental explosion from the the tanks, and of localizing the explosion if one be produced intentionally in such a cylinder.

I do not deal with the theory of this simple but effectual safety device, but the part taken by the porous substance in this case has been spoken of as analogous to that which infusorial earth plays in the case of dynamite. To me it seems more analogous to the principle employed by Sir Humphry Davy in the safety lamp, who found that flame would not pass through iron wire gauze of twenty-eight threads to the inch. Edmund Davy discovered acetylene in 1836, describing some of its more important properties in a communication to the British Association of that year. He found even at that early day that distilled water absorbed about its own volume of this gas; that it was evolved unaltered by heating, and adds:

"From the brilliancy with which the new gas burns in contact with the atmosphere, it is, in the opinion of the author, admirably adapted for the purposes of artificial light if it can be produced at a cheap rate."

The apparatus is extremely simple, and altogether consists of a tank of any usual form such as is used on every car lighted with either compressed city gas or compressed air enriched with gasoline vapor, as in the Frost carbureter system or in the Pintsch system. These cylinders are, in process of making, completely packed with asbestos disks or with porous brick of 80 per cent. porosity, and are then riveted together, unless made with one flanged head, and are then ready for use.

The cylinder that I now exhibit to you, shown in the accompanying cut, *Fig. 1*, is in size 6 inches by 30 inches, and accordingly has a capacity of about ·49 of 1 cubic foot, or a little less than ½ of 1 cubic foot. It is made of mild steel $\frac{1}{16}$ inch thick, is tested to 500 pounds pressure, and is computed to withstand more than 1,500 pounds pressure to the square inch. We employ a pressure of only 240 pounds, or 16 atmospheres.

In practice, to get the greatest capacity, about 43 per cent. of the mathematical volume of the cylinder should be occupied with acetone, the liquid which dissolves the acetylene gas, which, saturating the asbestos or bricks, takes the form of a film of liquid lining the walls of the cells of the bricks. A ready means of introducing the acetone is to exhaust the air and then connect the inlet with the acetone and allow it to be drawn in. If now the acetylene be pumped into the cylinder, it is taken up by the acetone in the same manner as if the acetylene were pumped into the body of the liquid and allowed to bubble up through it. When the acetylene is pumped in at a moderate rate—and a half hour is taken to charge a large cylinder sufficient for a railway car—the acetylene dissolves in the acetone as fast as it is pumped in. If there is need of charging the cylinder more rapidly, it may be charged to a pressure of 15 atmospheres, from which it subsides in a short time to 10 atmospheres.

But the capacity of a tank for acetylene when thus equipped is 100-fold the mathematical contents. A standard tank on a railway car is 10 feet 4 inches in length and 19½ inches internal diameter, containing about 21·5 cubic feet. By Boyle's law, if illuminating gas or air or acetylene be pumped into this tank without this equipment of brick and acetone, or any filling, at 10 atmospheres, 10 fold the contents will be contained; that is, 215 cubic feet of gas at 150 pounds pressure; but with the asbestos and the acetone in the proportions named, 10-fold this amount may be pumped in at the same pressure, or 2,150 cubic feet of acetylene; and if double this pressure is employed, 4,300 cubic feet may be stored therein at but 300 pounds pressure, and when the pressure is relieved from the tanks the acetylene comes forth unaffected by the acetone, of which there is but a

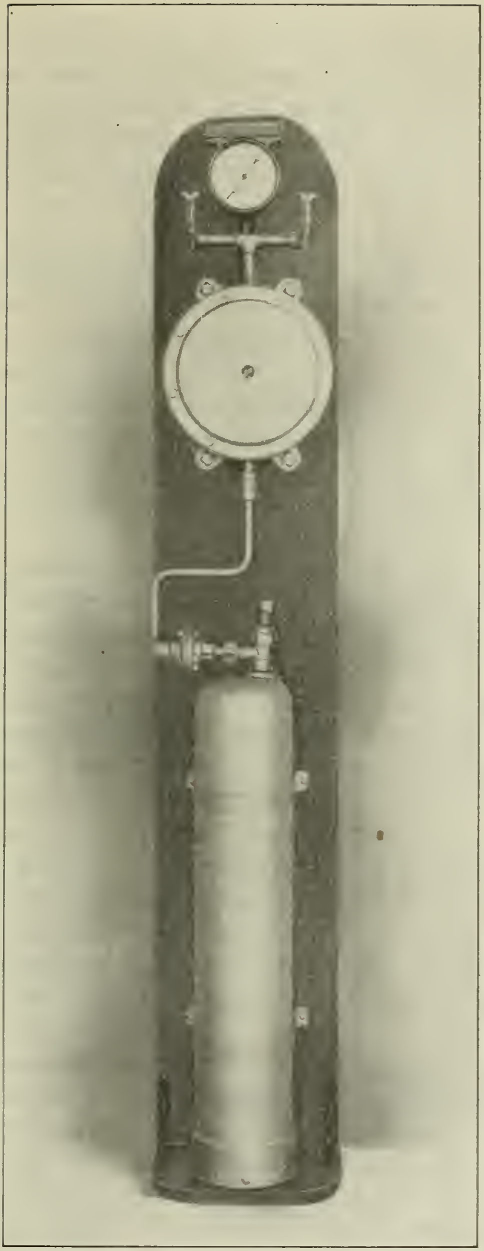

FIG. 1.—Exhibition cylinder, 6 x 30 inches, about one-half of one cubic foot, holding 80 cubic feet of acetylene at 16 atmospheres.

trifling loss. There remains in the acetone an original charge of 25 volumes of acetylene at atmospheric pressure and at ordinary temperatures. When the apparatus is charged a second time all the second and subsequent charges of acetylene are recovered again on relieving the pressure.

While the great storing capacity of these inventions combined as a whole is always a striking feature, the principal object sought was the perfect safety of the process, and this has been demonstrated completely.

A steel tank, about 3 feet long and 4½ inches external diameter and 3½ inches internal diameter, containing 7 liters, was filled with porous bricks exactly fitting it, which after being fitted in the tank were saturated with 3 liters of acetone. A standard manometer was attached to the service-pipe and this to a pump connected with a gas-holder containing pure dry acetylene. When 5 atmospheres had been compressed into the cylinder, it was blown off, in order to displace the air within it, which compresses but does not dissolve in acetone. Starting again with the manometer at zero, 200 liters were pumped in in twenty minutes. The cylinder was slightly warm to the touch, but the pump and other apparatus were cold. At the end of eighty-seven minutes 700 liters had been pumped in, the manometer stood at 12·5, the general apparatus was cold and the cylinder almost as cold as at the beginning. The receptacle was then connected with an electric machine capable of producing a spark, a plug having been inserted before the pumping began; the electric machine was worked rapidly while the cylinder was in an outside passage, thus producing a spark within the cylinder. On opening the receptacle the first brick, about 1·75 inches, which had been cut away to pass the rivet heads and packed around with asbestos, was found to be covered on the top with carbon, which had also covered the inside of the cap of the receptacle. The carbon had worked down inside of the cylinder as far as the second brick, the acetone had saturated all parts of these two bricks, which were then taken out. Some of the carbon had filled the space between the first and second bricks, but not entirely. Upon digging out the second brick it was apparent that there had been no explosion further than the space between the first and second bricks.

M. Fouché has made many experiments with pressures up to 35 atmospheres, each one showing that with this simple apparatus we render inexplosible, not only the free gas, but also the solvent and absorbing liquid.

A similar receptacle charged with acetone and gas was connected by a steel pipe provided with a stop-cock and acetylene allowed to blow off sufficiently to expel all the air. The outer end was then sealed up and placed over two large Bunsen burners, which heated the steel pipe nearly to a white heat. On taking the apparatus apart, it was apparent that the acetylene which had been dissociated in the pipe had not communicated its explosion to the chamber itself.

Vieille, in making his own experiments for the city of Paris, found, and stated officially in his report, that this apparatus had for its effect to transform to a condition of security these recipients filled with a porous substance and charged with dissolved acetylene.

The apparatus has been raised to the boiling point and retained there, the experiment occupying more than three hours, without raising the pressure to more than forty-two atmospheres.

A gratifying circumstance and one contributing to safety is that when an electric spark was made in a steel cup at 200 pounds, the manometer being put on showed only 135 pounds pressure. In another instance, where a much larger tank was subjected to the sparking test, the manometer, standing at 150 pounds pressure before the spark, immediately after stood at 125.

Similarly, Lewes records that on heating pure acetylene in a curved tube over mercury to a temperature sufficient to soften hard glass, the volume of the gas decreases and at the same time tarry products make their appearance. In one experiment at the end of a half hour 97 per cent. of the original acetylene had disappeared, leaving only 3 per cent. untouched, whilst almost all the hydrogen of the acetylene was found in the liquid and solid products of the reaction. When higher and more prolonged temperatures were employed, the acetylene being passed through a red-hot tube was almost entirely decomposed into carbon which was deposited and hydrogen which was set free, always with decrease of volume.

In the details of one of the experiments recorded by Lewes, the volume of the acetylene before heating was 309 cubic centimeters, and after heating 174·2, or a little more than one-half the volume.

The fact that acetylene contains only its own proper volume of hydrogen, that of all the hydrocarbons it contains the least hydrogen, that hydrogen is occluded in the carbon that is formed by dissociation, that the liquid and solid products that result from the contact of acetylene with red-hot iron all contain more hydrogen than the acetylene contains, and that polymerization of part of the acetylene takes place, all bear upon the interesting fact that acetylene when in contact with red hot iron decreases in volume.

The pressure of acetylene dissolved in acetone confined in a tank decreases one-half for a decrease of 54° F.; but, as might be expected of a tank equipped with this large body of asbestos, the response of the tank is exceedingly sluggish to changes of temperature.

Thus, in a test made for Dr. Charles B. Dudley, of the Pennsylvania Railroad, a small tank 57 inches in length by 4·75 inches in diameter, charged with acetylene at 3 atmospheres, was maintained for three days at about 60° of temperature F. The day before the test it was put into an upright zinc cylinder out-of-doors in very cold weather, the thermometer at seven o'clock in the morning of that day and the day of the test registering 12° above zero.

On arriving for the test, the tank having been standing in the zinc cylinder for a day, the manometer showed 2½ atmospheres with a temperature of about 14° F. The space between the tank and the enclosing cylinder was then filled with a freezing mixture consisting of 10 parts of ice, 5 of salt and 2 of nitrate of ammonia, producing an intense cold registering 14° below zero. In a half hour the pressure descended to 2 atmospheres. In three hours the pressure was 1 atmosphere, and the temperature near the top about 12° below zero. It was thought to be much colder lower down in the tank. The gas was turned on to three burners, the tank still standing in the freezing mixture, but the gas flowed freely. Ten feet of gas were thus taken from the cylinder in about one hour and a quarter.

The next day the tank was raised to a temperature of 60°, but it took two hours to do it. Ten feet of gas had come out the day before, and 20·5 feet the second day, and although the manometer showed no pressure, the gas came forth when the valves were taken off freely, showing a thick smoky flame 18 inches long with considerable pressure.

Another tank was charged to 10 atmospheres at zero, and then raised to 80° without the release of any gas. The maximum pressure was 350 pounds, but it required from 3.15 in the afternoon to 4.21 to do this in the case of a tank about 3 inches in diameter.

Car No. 234, on the Lackawanna R. R., equipped with four lamps, each with 3½-foot burners, and one in the toilet-room, thirteen lights in all, ran continuously from March 14 to April 16, 1902, about eight hours a night, and the tank was then about half full, showing 75 pounds pressure. In all, the car ran, according to official records, 360 hours without recharging; or at the rate of four hours a day, which is the common service of a car, it ran ninety days without recharging. (*Fig. 2.*)

The yacht "Oneida" ran all summer lighted from one tank 7 feet long and 19½ inches in diameter without recharging.

The portability of this system might be illustrated by a tank-car having four tanks with an aggregate capacity of 1,500 cubic feet. This would carry at 10 atmospheres 150,000 cubic feet of acetylene, conveying gas for 300,000 hours of light with one flame, or sufficient to maintain twenty lights 15,000 hours, or at four hours a day sufficient to maintain twenty lights for 3,750 days, or over ten years. This would be sufficient to light 120 cars for a month, or to

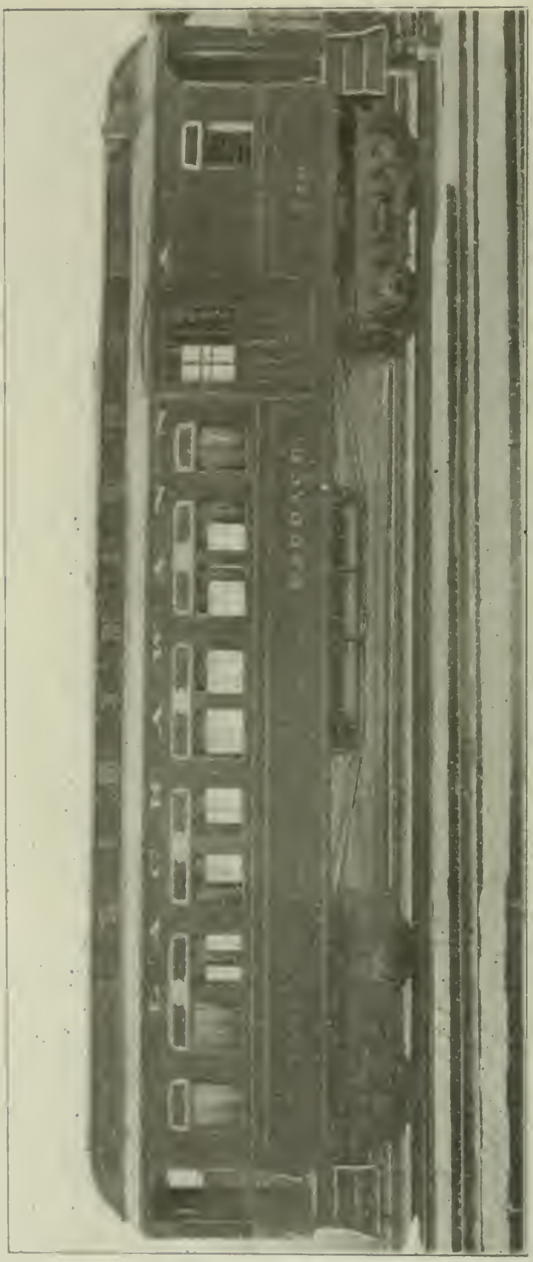

FIG. 2. D., L. & W. car, lighted with acetylene in safety tanks.

light a freight warehouse and switching station employing 100 lights nine hours a night for a year without recharging.

Signal towers and the adjoining switches, perhaps twenty in number, furnish a special lighting problem. Tanks charged with acetylene dissolved in acetone can be transported throughout a railroad system by freight, and the empty tanks exchanged for the full ones, with no greater trouble than would be required to send direct the calcium carbide to the separate stations for generating the gas on the spot. All the acetylene that is produced by 100 pounds of calcium carbide can be transported in a 5-foot tank.

This invention has a highly respectable origin, and it has passed its experimental stage. It has been for more than two years last past in use in Paris on the cars of the Chemin de Fer de Funiculaire de Belleville, and it has been pronounced a perfect success. It has to some extent been used in construction work by the city of Paris itself. It is used in more than 300 houses and factories in and around Paris. It has been authorized by the insurance companies of Paris. It has been authorized and permitted by the eminent engineer Vieille, having charge of explosives and illumination for the city of Paris, and his official permit is issued for its use within the city.

In England it comes under the Explosives Act of 1875, a statute enacted before acetylene came into commercial importance, but which is sufficiently broad to cover it. Under the provisions of that Act, orders of council are issued from time to time, and one was issued on the 26th day of November, 1897, under Section 104, which declared that acetylene, when liquefied or when subject to a certain degree of compression, should be deemed an explosive within the meaning of the Act.

But on the 10th day of April of the year 1901, the Honorable Charles T. Ritchie, one of His Majesty's principal Secretaries of State, having examined this invention, certified that it had been shown to his satisfaction that acetylene, when compressed into these porous bricks, with or without the acetone, was not possessed of explosive properties, and he thereupon issued his order under the Act in question that it should not be deemed to be an explosive within the meaning of that Act, provided certain conditions were observed, such as that the cylinder should be tested and marked, and that an inspector should have access to the cylinders.

Acetylene will not supplant city gas, nor electricity, nor oil, nor candles; but for special applications, particularly for railway cars, even electric cars, small railway stations, lighthouses, piers, country houses, buoys, small towns, temporary installations for fairs and conventions, boats, automobiles, railroad signals, lantern projections and photography, it is well adapted.

If, as Huxley says, out of the contemplation of pumps grew the discussion about Nature's abhorrence of a vacuum, whence it was discovered that Nature does not abhor a vacuum, but that air has weight, and *that* paved the way for the doctrine that all matter has weight, and that the force which produces weight is co-extensive with the universe; in short, bringing in the theory of universal gravitation and endless force, no sincere and patient study of a problem in the applied sciences is likely to be without enlightenment in the study of pure science.

The *commercial handling* of acetylene opens up vistas of discovery even in the recondite problems of life. We cannot doubt that in the progress of mind working upon fixed and verifiable data as its material such discoveries will be made. If to others it seems improbable, it was Aristotle who observed:

"Perhaps one might call this very thing a probability, that many improbable things will happen to men."

CURIE EXPERIMENTS WITH RADIUM.

Professor Curie has announced to the French Academy of Sciences that radium possesses the extraordinary property of continuously emitting heat without combustion, without chemical change of any kind, and without any change in its molecular structure. Radium, he states, maintains its own temperature at a point 1·5° C. above the surrounding atmosphere. In other words, the quantity of heat evolved is such that a pure radium salt will melt more than its own weight of ice every hour, and half a pound of a salt of radium will evolve in one hour heat equal to that generated by burning one-third of a cubic foot of hydrogen gas. Despite this constant activity, the salt apparently remains just as potent as it was at the beginning.

THE FRANKLIN INSTITUTE.

Stated Meeting, held April 15, 1903.

The School City.

By Wilson L. Gill,
General Supervisor of Moral and Civic Training, Public Schools of Cuba under the American Administration.

Object of Public Instruction.—The greatest aim and object of public education is to cultivate in the individuals to be educated a good conscience, and to secure for them a wise and resolute self-government and the desire and ability to co-operate for the common good; or, in other words, a good character. Sharpening the wits and storing the memory with facts, the apparent object of schools, colleges and universities, is, in reality, but a minor matter, and will easily and necessarily follow the attainment of the chief end of education. A practical method which may be used in a wholesale way in all schools, for students of all ages, which makes it possible and easy for teachers to lead their pupils to cultivate good conscience, to govern themselves wisely and to co-operate for the general good, will do for the cause of morality, education and human welfare, what the steam-engine and electric apparatus have done for the cause of manufacturers and human comfort. The School City method of popular government has proved itself to be fully adequate to this great purpose. This large claim is not rashly or unadvisedly made. It is not claimed, however, that this method can take the place of other needed progress in public instruction, made necessary by the social, political and industrial evolution which has accompanied the general introduction of machinery and the immense emigration from the farms to the cities, all of which have a direct bearing on the moral and civic conditions, and, consequently, call for notice in this place. The changed conditions demand, for the public thrift and the public safety, that children be trained in productive industry, and that intelligent attention shall be given to making a healthful division of the children's time among bookwork, productive industry, recreation and rest, and to the proper housing and feeding of the people. Let it be noted that by productive industry is not meant that kind of manual training in which a child is engaged only two or three hours a week, and in which he uses up material furnished out of the public funds and does not give a visible and commercially valuable and adequate return.

Teaching the precepts of morality and the doctrine of one's relation to his fellows and to his country, is as old as literature. Enterprising and true teachers have always sought for ways to put such teachings into practice, and they have been successful as teachers in proportion to their success in this matter. A well-developed method of practical character-building and training in morality and in performing the duties and exercising the rights of citizenship in a thoroughly systematic, wholesale and successful way is new. Cuba is the first country in the world to require such training in the public schools. Every country should require it as a matter of public policy, and the highest legislative power in the State ought to give authority to it. There are many school teachers and officers who are bright enough to see the importance of training the children in citizenship and to form good characters, and there are many who are sufficiently unselfish and self-sacrificing to perform the labor of thinking about and installing what is to them a new method in their schools. Such teachers should be encouraged to begin the work without waiting to be compelled by law. Even such enterprising ones need the encouragement and help of constant supervision by a competent and legally authorized specialist in moral and civic training. Such special supervision is at least as important as State supervision of any branch now taught in the schools. This is necessary for many reasons, a notable one being that many teachers who have had no experience in the use of the method and do not fully understand the principles involved, think it would redound to their credit if they should change the plan and thus make it appear to be wholly or at least in part their own. Such ones generally fail in accomplishing the object of the School City, and the whole plan is abandoned, unjustly discrediting the movement. Some of these same teachers would have succeeded had they been under competent supervision.

There are school teachers and officers who will not take the trouble to introduce this method. Whether or not the latter are in the vast majority may not be of much importance. That there are any such, is sufficient reason for looking to the higher powers for favorable decision in this matter.

Police Court in a Havana School City.

A Question for Statesmen.—Whether the children of a nation shall be trained as subjects of a monarchy, as is being done ordinarily throughout the world, or as self-respecting, co-operating citizens of a republic, is a question that demands the attention of broad-minded statesmen, whose insight is sufficiently penetrating and whose outlook is far-reaching enough to enable them to discover a vast peril to the great republic at the present time, whose judgment is good enough to enable them to recognize the remedy when it is placed before them, and who have enough back-bone to act promptly and effectively in this matter. They should put it beyond the choice of all who might hinder. They should lay down the law that the schools of a republic shall train its people while children as citizens, not as subjects, and that they shall make the developing of good character in the children the first aim and a specific practical part of the daily work of the schools.

Facts and Philosophy.—In the United States, the greatest and most successful of all republics, the one great failure in the government is the municipality, and this is a sore spot that threatens death to the republic. It is worth while to analyze the situation, with a view to seeing the principal causes for the weakness in American municipal government.

The most glaring defect is that a great mass of the educated people do not go to the primaries, and they neglect their municipal duties. That leaves the effective political voting power in the hands of those who are comparatively uneducated. They in turn are organized and manipulated by men who make a business of municipal politics, not always, but generally, for the money they can get from the public treasury, and, by means of blackmail, from private persons and establishments, and especially from those engaged in forbidden or restricted practices and business.

Lost Liberty and Death.—"Eternal vigilance is the price of liberty," and the educated people have not paid the price. Among the consequences are insufficient results from the expenditure of public funds, more disease and a higher death-rate than there should be. The people have lost a part of their liberty, if, because of the inability or dishonesty of the public servants, they must labor additional hours to pay their taxes, and quite as much so if they lose life because of bad drainage, dirty streets, impure water, bad food or other evils which should be prevented by the government.

Schools and Colleges are to Blame.—As this state of affairs is charged to the account of educated people, let us take a closer look. We see practically the following: The uneducated men, who can be easily handled by the machinery of the bosses, all vote; most of those who have had but little schooling vote; less of those who have had much schooling vote; a college and university education is almost a certain guarantee that a man will not attend the primaries or perform his other municipal duties. This seems to throw the blame on the schools, colleges and universities. They teach right principles. The fault does not seem to be in the books. The fault is in the school management. From the primary school till the man graduates from the university he is made to feel and to know that he has simply to obey, and nothing further to do with the government of himself and his fellows, and that he is a tattle-tale and sneak if he brings a wrong-doer to justice, and is mean and dishonorable if, when called upon by the authorities to testify, he does not so shape his testimony as to clear the offender.

Anarchy Fostered.—Under this pressure, secret opposition and disloyalty to constituted authority is constantly fostered. Many pupils regard their pleasure and interest as opposed to those of their teachers, who are apt to be thought of as spies and in some cases as enemies, instead of friends and guides.

Old-fashioned school government is monarchy, in which the teacher endeavors to rule by means of his conscience and arbitrary authority, and the political results are as we see them in the municipalities of the United States.

The Remedy.—The recognition of the cause of the evil is almost a declaration of the only remedy, which is to systematically train the individual to wisely cultivate his own conscience and be governed by it, rather than by that of the teacher; to co-operate with his fellows for the common good, rather than for mischief: to form the habits of law and order, rather than those of anarchy. In other words, the remedy for the apathy of educated men, in reference to their municipal duties, which is in effect anarchy, not of the lowest, but possibly the most dangerous type, is to train them while young to think and act to form the habits of citizens, instead of, as at the present, training them in the schools and colleges as subjects of monarchy.

Plan of School City.—The plan of the School City is to organize the children of each school, under a charter given by the higher authorities, as citizens of a municipality. These citizens elect a city council, who, in one phase of the plan, in turn elect a mayor, judge and other administrative and judicial officers. The mayor appoints his cabinet and subordinates, and has power to remove them at will. Nomination by petition, proportional representation and the initiative and referendum enable the whole body of citizens to express and enforce its will at any time, either with or independent of its representatives. Elections, for several reasons, occur frequently—once in ten weeks—and experience has shown that it is desirable to make the term of the police officers short. In most primary schools every citizen not elected or appointed to some other office is a candidate for a place on the police force, for which a high ideal of gentility and kindness is set.

I suggest the following code of laws, leaving the children free to accept, change or reject them and to make additional laws as circumstances require. They invariably accept them without change, and generally with much enthusiasm. The whole code is given to show how short and comprehensive it is.

SCHOOL CITY LAWS.

CHAPTER I.—THE GENERAL CITY LAW.

Do to others as you would wish them to do to you. This is the natural law, without which no popular government can succeed, and it is the general law of this School City, to which all other laws and regulations must conform.

CHAPTER II.—THINGS PROHIBITED.

ARTICLE 1. Do not to others that which you would not wish them to do to you.

Order.

ART. 2. Anything which disturbs the order in halls, class-rooms, or in any place within the jurisdiction of the School City is prohibited.

ART. 3. Anything which is profane, rude or intentionally unkind or impolite is prohibited.

Cleanliness.

ART. 4. Anything which detracts from the neat and orderly appearance in our School City is prohibited.

Health.

ART. 5. Anything which detracts from the healthful condition of our School City is prohibited.

Public and Private Property.

ART. 6. Anything which mars or destroys property in our School City is prohibited.

CHAPTER III.—DUTIES.

ARTICLE 1. Every citizen is in duty bound to call the attention of the authorities to any violation of the laws of this School City.

CHAPTER IV.—PUNISHMENTS.

ARTICLE 1. Any citizen violating any law of this School City shall be subject to punishment not less than a reprimand and not greater than a withdrawal of the rights of citizenship.

ART. 2. Every punishment must be approved by the principal of the school before it is carried into execution, and then promptly put in effect.

CHAPTER V.—OFFICERS.

ARTICLE 1. The police commissioner, with the consent of the mayor, shall appoint one chief of police for the school, and one captain of police and four policemen for each room. Appointments, before going into effect, must be approved by the City Council.

CHAPTER VI.—TERMS OF OFFICE.

ARTICLE 1. The term of office of all officers, unless otherwise provided, shall be until the next general election and until their successors are appointed or elected.

ART. 2. Captains of police shall serve two weeks, and policemen one week, unless sooner removed for cause by the commissioner of police.

Good Results.—Many instances of fine moral results are reported from the different schools. Of course, the results are not uniform, as the School City is not an automatic machine out of which all must come in exactly the same shape. It is a method, and its degree of success depends upon the interest and skill of the principal and teachers who use it.

Almost without exception, when a troublesome boy accepts the responsibility of an office in the School City, he instantly puts off his ugly old character and assumes one of glad obedience and respect for authority and others' rights, and at once begins to help in all that is right, instead of to hinder, as was his habit. If, then, the teacher under-stands the method and is true to it, he will be friendly to the boy, consult and encourage him, sympathize with him and help him to maintain his enthusiasm, and the boy is saved permanently. Women teachers, with correct intuitions and hearts full of sympathy, if they understand the simple method, will seldom fail to make the work of regeneration permanent. Men or women who study and treat a boy as they would a trilobite, a noxious weed or poisonous snake, will almost surely fail to give the necessary aid to maintain the boy's enthusiasm and, of course, he will very soon, if not at once, begin to relapse into his former ugliness. The condition of the School City is an almost exact index of the character and condition of the head of the school and of the teachers.

The limits of this article will not admit of the introduction of official reports from American and native officers in Cuba, and unofficial reports of teachers in American schools, but they are numerous and favorable and many may be found in the library of the Franklin Institute.

Experience emphasizes the fact that best results demand good printed suggestions and helps for the teachers and children, and intelligent and authoritative supervision.

Monarchy and Democracy in Great Britain and the United States.—While the growth of the spirit of democracy has gone on for centuries in Great Britain, till to-day England is in name a monarchy, but in fact a great, free, democratic republic; in America, the vestiges of monarchy not wiped out by the Revolutionary War have gone on developing, till in some of our cities and States we have the name and machinery of a democratic republic, but in reality the spirit and the actual domination of monarchy.

The "bosses" or "leaders" are not to blame for this condition. The conditions have produced the "bosses," who are our real rulers as much as if we called them "kings" or "czars." Except by some sort of revolt against the present order of things in our municipal and State government, the only way in which a public-spirited man can render political service in those cities and States where boss rule has been established, is by making himself the boss or sub-boss or entering the service of the existing uncrowned king, or else by helping to abolish the educational method and conditions which have prevented the educated men, while children, from forming the character and habits which are necessary to an independent, unselfish and faithful citizenship; and to establish such a method and condition in the schools as will aid the young people to build the character and establish the habits of ideal citizenship, successful steps have been taken both in the United States and Great Britain to establish the School City for this purpose; but the movement is young in both countries and needs the support of every lover of his race to whom the knowledge of it may come.

Meeting of City Council in a Havana School City.

Two Bosses.—Within a short time I have come in close contact with two political bosses. One is a highly educated, refined American gentleman, who derives his wealth from his private commercial enterprise. The sincerity and depth of his interest in educational matters and the general welfare and happiness of his fellow-countrymen is evidenced by the fact that his daughter, with no financial necessity, is an enthusiastic kindergartener, and he is proud of it; and though he sees that faithful, intelligent, tactful training in citizenship in all the public schools would mean the ultimate doom of bossism, he is ready to give his hearty support and co-operation for the general introduction of the School City. In a true democracy, it is such men that the people delight to trust and to honor. The other boss I saw and heard angrily denounce, with profane and vile language, a lady official, and taunt her as being a college graduate, because she raised her voice against impure methods in the appointment of teachers. This was in the presence of nearly a dozen of her official colleagues, all men, stalwart in body, but not one dared a word in protest against his insults to womanhood, education and the spirit of democratic republicanism. All were ashamed of the outrage, but they were in his power, and probably felt that they were helpless to oppose him. The object of this allusion to the two bosses is neither to condemn nor defend this development of monarchy in our midst. If the people want a monarchy under the name of boss government, by all means let them have it; but I am acting on the presumption that they do not want the spirit and conditions of monarchy in city and State affairs, any more than they do in national government. My object is to call attention to the fact that there are two kinds of bosses, and that some may be true gentlemen and patriotic, who are serving the welfare of their neighbors as best they can under existing conditions, and that they will gladly co-operate to establish in the municipalities a government more directly in the hands of the people, just as soon as the educated and best elements of the people are willing and prepared to habitually defend their rights and perform their duties as citizens.

Industrial, Moral and Civic Evolution.—When our Republic was young, the mass of her people lived on farms. Boys and girls went to school only two or three months in the year. For the rest of the time they labored with their parents in the fields and at the spinning-wheel and loom, always under moral, religious, industrial and civic influence and training. The hoe and spade of the Colonies have given way to the steam-driven machines on the vast prairies; the spinning wheel and hand-loom to immense cotton and woolen mills; the country forge to stupendous rolling-mills, furnaces, foundries and forges. By such means the children of to-day are separated during work hours from their parents. The public schools, which consume these released hours and years in training the intellect and cramming the memory, make no systematic, intelligent endeavor to furnish that kind of character-training which our ancestors received from their parents. The War of the Revolution failed to wipe out that vestige of monarchy which lurked in the government of the little country school. That was too insignificant to be thought of, for in those days the American citizens' character was built in the open country, under the influence of their parents, the heroes of the Revolution. Now, American character is developed in great swarming buildings, under the weight of a heavy, crowded, intellectual curriculum, and that vestige of monarchy which was left in the school has grown, with the increasing months of the school year, to large proportions and is wielded by masters, who themselves have been trained as subjects, not as free men.

An Appeal.—Thus, the public schools and colleges, boasted bulwarks of our liberties, have unwittingly,.but ceaselessly, nursed the spirit of monarchy, and through childhood and youth subjected our whole people to it, to that extent, that when they reach the age of manhood they do not go to the primaries and municipal polls, and thus they fail to enter into their heritage of citizenship. This is what has made government by the bosses possible. Fortunately, some of the municipal bosses, maybe many of them, are so patriotic that they would gladly see political power restored to an intelligent, active, faithful citizenship, and I hereby appeal to all American patriots and friends of a government of the people, for the people, and by the people, to join in this movement to provide that every child who enters a school-house shall be treated while there as a free man, and be confirmed in the character and habits of a free-born, faithful and patriotic American citizen, not only ready to die, if necessary, for his native land, but what may be more difficult and quite as important, actually living for his country, patiently and fearlessly defending his rights and faithfully performing all his public duties.

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Maria Lopez, General Superintendent of Schools *ad interim*, p. 4, endorses Mr. Gill's work as important; on p. 28, E. B. Wilcox, Ph.D., Special Inspector of Schools of Cuba, reports most favorably on the School City.

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Civil Report of Brigadier-General Leonard Wood, Military Governor of Cuba, May 20, 1902, Vol. I, part 2. Report of First-Lieutenant Matthew E. Hanna, Commissioner of Public Schools, p. 46, emphasizes statements in previous reports.

DEVELOPMENT OF THE GAS ENGINE.

Of late years the size of gas engines has much increased. Many makers are now building machines of 2,500 horse-power, and are ready to double this efficiency. The development of large gas engines is closely connected with the evolution of the fuel-gas processes, and it is noteworthy that the first gas engines in England above 400 horse-power were operated with producer gas, while many of the large gas engines in Europe have been built for use with blast furnace gas. In August, 1902, two English firms had under construction over fifty gas engines varying in size from 200 to 1,000 horse-power. A classified list of engines made or making shows 327 such, with an aggregate horse-power of 182,000, or about 560 horse-power per machine. The last volume of the United States census reports 18,500 combustion engines in the country, with a total capacity of 165,000 horse-power, or only about 9 horse-power on the average. This state of things is not likely to last long. One American firm has already sold over 40,000 horse-power of large engines, most of them of 2,000 and several of 1,000 horse-power. Another has recently built two 4,000 horse-power gas compressors and a number of 1,000 horse-power gas engines. The gas engines of the large sizes are extensively used for generating electric light and power, but there is a decided tendency to employ the smaller sizes direct as motors. Cheap fuel-gas processes will bring the gas engine to replace the electric motor for very many purposes, and we may look for development along these lines in the near future.

Dr. Robert H. Thurston, of Cornell University, says that two controlling tendencies mark the improvement in the efficiency for commercial purposes of every product of the engineer's labor; their resultant varies as the one or the other is in the ascendant. These are increasing costs with increasing efficiencies, and advancing expenditures with diminishing gain. As the outgo for increments of efficiency and economy continues, the gain by increased efficiency is partly, or wholly, or more than wholly, compensated by the simultaneous increment of cost. With the crude apparatus of the earlier stages of uneconomical and incomplete industrial systems, there usually exist great opportunities for improvement by refinement of the apparatus and by systematizing the industry at, often necessarily, increased cost in the form of invested capital. Later, the possibility of further improvement lessens, and the costs to secure any given gain increase, until it ultimately becomes a fact that more must be paid for a given gain than it is worth, and the net outgo on the improved apparatus or system becomes, interest and sinking fund included, more than that on a less perfected machine or system. What may be called a "golden mean" is thus always found at that stage at which the cost of additional economies will exceed the necessary cost of securing them, and where the result of securing them is loss rather than gain. The resultant of the two tendencies takes a direction which thus tends toward the unprofitable, and a limit may thus always be expected to be found, beyond which further refinement is financially undesirable.—*Cassier's Magazine.*

NOTES ON NICKEL-STEELS.

M. Guillaume, assistant director of the International Bureau of Weights and Measures, has been making for several years a special study of nickel-steels. He has found in the series of alloys of iron and nickel a curious anomaly, of which one of the characteristics is a considerable falling off in expansion as compared with that which the ordinary law of mixtures should give. He has succeeded, according to Henri de Parville, in the *Journal des Debats*, with the assistance of the Société de Commentry Fourchambault, in obtaining alloys which contract when heated, a little after the manner of india-rubber. It is a curious result from which many important applications can be drawn. For example, there can be obtained alloys with so little expansion that it can scarcely be measured by the most delicate processes. A nickel-steel wire has been made which had an expansion of only 0·4 millimeter in a length of 1 kilometer, between 0° and 20° C. (0·0253 inch in a mile, between 32° and 68° F.).

The value of the new alloy for the compensation of chronometric apparatus and the measure of geodetic bases can be understood. In metrology the determination of variations in the length of the rods forms one of the great difficulties among the very difficult operations of geodesy.

M. Guillaume has also studied the changes which time produces in the alloys. The stability of the alloys is wholly sufficient for geodetic purposes and for the construction of compensated clocks. The Swiss manufacturers are already making compensators on which temperature has almost no effect. These nickel-steels contain 36 per cent. of nickel.

Certain alloys of different composition undergo curious changes when they are plunged into liquid air at a temperature of 180° below zero C. (292° below zero F.). A bar containing 30 per cent. of nickel, when thus heated, became permanently lengthened under the influence of the cold, instead of being shortened. The material underwent profound changes, as crystallizations indicating a transformation of the metal were seen to form on the polished surfaces. These investigations are of both scientific and practical interest.

CHEMICAL SECTION.

Stated Meeting, held January 29, 1903.

The Census of Manufactures of 1900.

By Charles E. Munroe.

Provisions for the periodic taking of a census was made at the founding of our Government; for Article I, Section 2, of the Constitution of the United States, directs that an enumeration shall be made within three years after the first meeting of the Congress of the United States, and within every subsequent term of ten years in such manner as they shall by law direct. The incorporation of this requirement in the initial law of our land has aroused much comment. Thus, De Jonnés has declared that the United States presents a phenomenon without parallel in history, viz.: "That of a people who instituted the statistics of their country on the very day when they founded their Government, and who regulated by the same instrument the census of inhabitants, their civil and political rights, and the destinies of the nation."

The taking of a census was not a new departure in government in 1787, for the Romans conducted full and minute enumerations, and it is with this people that the term "census" originated, but the United States was the first of modern governments to institute a system for the taking of a census periodically, and we have extended it to a degree not yet approached by others. As pointed out by Gen. Francis A. Walker, the framers of the Constitution, in incorporating in that instrument a provision for a national census, were not actuated by purely philosophical motives or by sentimental considerations, but the requirement was a political necessity arising from the representative form of government based on population as set forth and accepted in the Constitution.

For this reason at the outset an enumeration of the population only was contemplated, and the censuses of 1790 and

1800 were practically confined to statistics of this character, but with the machinery at hand there has been a constant tendency to put it to more extended use. The first enlargement of the scope of the census occurred in 1810, when the agents of the census were by law required to take account of the several manufacturing establishments and manufactories within their several districts. This extension was somewhat due to the influence of Alexander Hamilton, who, as Secretary of the Treasury, in 1791 submitted to Congress a "Report on Manufactures," which fairly represents the industrial situation in the United States shortly after the organization of the Federal Government, and just prior to the opening of the nineteenth century; but it was directly due to Albert Gallatin, who, as Secretary of the Treasury, in response to a resolution of the House of Representatives of June 7, 1809, made a report which is an admirable summary of the condition of American manufactures at that date, since, in concluding this report, Mr. Gallatin recommended that the law for taking the third census should be amended so as to require the marshals and their assistants to return an account of the several manufacturing establishments in their districts and divisions; and in accordance with this recommendation Congress, on May 1, 1810, passed an amendment to the Census Act authorizing the Secretary of the Treasury to appropriate for this return $30,000 out of the $150,000 set apart by the previous Act for taking the census. Thus it is to Albert Gallatin that the credit is due that the United States began thus early, and before any other country, taking a census of manufactures, and this practice has been continued uninterruptedly, with the exception of the year 1830, up to the present time. And in this Act we find the first official recognition of the dignity of labor and the important position that it occupies in the development of a nation. It is not possible to estimate the influence which this has exercised in enabling us to reach the commanding position that we now occupy.

Naturally, as in the carrying out of all new enterprises, the methods used at the outset for the collection of statistics of manufacture were crude and inefficient. Thus the first industrial census of 1810 was taken without even the formality of a schedule, or definite instructions to the marshals, and necessarily the result forms no true measure of the industrial resources of the country at that time. In fact, the censuses of manufacture prior to 1850 were so imperfectly taken and compiled that it is not possible to use their data for purposes of exact comparison with the data of subsequent censuses. Certain of these reports even showed no aggregates for the United States or for each industry. Yet, nevertheless, they were useful in that they gave much valuable information regarding the industrial conditions and progress of the country.

For instance, in his Report on Manufactures, after enumerating seventeen different industries that were in 1790 carried on as trades in different localities, Hamilton describes a vast scene of household manufacturing, pointing out that cloths of woolen, flax and cotton and of mixed fibers, of many descriptions, for clothing and coverings, were "made in the household way, and, in many instances, to an extent not only sufficient for the supply of the families in which they are made, but for sale, and even, in some cases, for exportation. It is computed in a number of districts, two-thirds, three-fourths, and even four-fifths of all the clothing of the inhabitants is made by themselves. The importance of so great a progress as appears to have been made in family manufactures within a few years, both in a moral and political view, renders the fact highly interesting." The factory system of manufacture, so-called, in contrast to domestic and shop manufacture, had practically no existence in the United States at the opening of the nineteenth century. This system obtained its first foothold in the United States during the period of embargo and the War of 1812. The manufacture of cotton and wool passed rapidly from the household to the mill; but the methods of domestic and neighborhood industries continued to predominate, even in these industries, down to and including the decade between 1820 and 1830; and it was not until about 1840 that the factory method of manufacture extended itself widely to miscellaneous industries, and began markedly to force from the market the hand-made products with which every community had hitherto chiefly supplied itself. Apparently, until about the year 1850, the bulk of general manufacturing was carried on in the shop and the household by the labor of the family or individual proprietors, with apprentice assistants, rather than by the present system of factory labor compensated by wages and assisted by power. Though the census of 1850 is the proper starting point for the comparative statistics of manufactures for this country, it is not possible to so analyze the figures returned by that census as to determine with certainty the relative proportion of the products of factories to those of the household and the neighborhood shop; yet the statistics of subsequent censuses demonstrated that since that date the relative value of the products of the factories have steadily increased, until at the census of 1900 the value of the products of the shop and household represents but an insignificant part, say one-thirteenth, of the total value of the products.

During this period there has grown up a division of labor which has promoted efficiency and speed of production through specialization, and also the so-called system of interchangeable mechanism, which is distinctively and peculiarly American in its origin. And by the segregation of labor in factories, together with the abundant use of machinery, has come a continued diminution of the cost of manufacture, while economies have been effected that were not possible under the older systems. To note the advantages of the division of labor we have but to compare the modern shoe factory with the older shoemaker's shop, or the modern establishments for slaughtering and meat-packing, with the household methods formerly universally in vogue. In these last-mentioned establishments we have also a striking example of the almost complete prevention of waste of which the factory system permits. Of the system of interchangeable mechanism Prof. W. P. Trowbridge has said in the Census report for 1880: "The general growth of the 'interchangeable system' in manufacturing has had an influence in the development of manufacturing, agriculture and other industries which but few have hitherto appreciated. It may not be too much to say that, in some respects, this system has been one of the chief influences in the rapid increase in the national wealth. Two of the great industries, which constitute the basis of this wealth—agriculture and manufactures—depend now largely upon the existence of this remarkable feature in manufacturing, which has reached its highest development in this country. The growth of the system is due to the inventive characteristics of our people, and their peculiar habit of seeking the best and most simple mechanical methods of accomplishing results by machinery, untrammeled by traditions or hereditary habits and customs."

The means and methods employed in the gathering and presentation of the statistics of manufactures, which is the most difficult and complicated branch of census work, have, as shown in the History and Growth of the United States Census, 1790–1890, by Carroll D. Wright and William C. Hunt, been most varied. The direction has been put successively under the President of the United States, the Secretary of the State, the Secretary of the Treasury and finally in 1850 under the Secretary of the Interior, with whom it has since remained. By the law providing for the census of 1880 a census office was established in the Department of the Interior, and a Superintendent of the Census to be appointed by the President, by and with the consent of the Senate, specifically provided for. Up to 1880 all the statistics of every kind called for were collected under the supervision of the marshals of the United States courts through assistants appointed by them; but the law of 1880 entrusted this duty to a body of officers especially chosen for the work, to be known as Supervisors of Census. Their number was more than twice that of the marshals then in office, and this Act provided the means for securing not only a higher degree of local knowledge on the part of the supervisor, which was of great value in the subdividing of his district, but also a closer and more direct supervision of the actual work of enumeration. They were charged with the selection and instruction of the resident enumerators, the scrutiny of their returns and the transmission of these returns to the office. This law further provided that the schedules of manufactures could be withdrawn from the enumerators of the several subdivisions, whenever the superintendent should deem it expedient, and the collection of these statistics charged upon experts and special agents to be employed without respect to locality, and under this provision the schedules for manufacturing industries were withdrawn in 1880 from the enumerators in 279 cities and the taking of these statistics given to special agents, while expert special agents were designated to collect statistics relating to certain specially selected industries of importance throughout the country. These expert special agents were further charged with the classification and analysis of the returns for these selected industries and the preparation of reports upon them which were published as monographs.

The schedules or blank forms containing the interrogatories upon which to take the returns, have likewise varied. In 1810 and 1820 a separate schedule for manufactures was used. In 1840 one schedule was used in common for statistics of mining, commerce, agriculture, manufactures and fisheries; in 1850, 1860 and 1870 one schedule was used in common for manufactures, mining and fisheries. In 1880 there was not only a return to a schedule for manufactures alone, but, as the law permitted special inquiries into selected industries, special schedules were introduced, there being forty-nine such special schedules and one general schedule used. In 1890 there were seventy-six special schedules and one general schedule for statistics of manufactures, while in 1900 there were thirty-two special schedules besides the general schedule. In the special schedules even, there has been a lack of uniformity in the different censuses, both as regards the industries selected and the queries that were put. Thus in 1890 the electrical industries alone were given twenty-seven special schedules, on which 2,240 questions were asked, while prior to this date there was no separate schedule for this industry, and in the census just completed there was but one supplemental schedule for it, containing eighteen questions. These are but a few among the many variations in means and methods of the different censuses, which were largely due to the temporary nature of the work; to the clamor for detailed data on a wide variety of subjects; to the absence of trained advisors and to the character of the legislation under which the enterprise was carried out at each decade. As pointed out by Director Merriam in the *North American Review* for January, 1900, "The indications are that, in the decades that are past, as the time approached for making the required enumeration, the plan for doing the census work was always hastily devised, and thus a temporary and spasmodic atmosphere was given to the whole enterprise. It seems to have been the idea of those who shaped the census legislation in the past that the work did not need any well-defined plan, but that a large temporary force could be gathered together, and the information concerning population, agriculture and manufacturing industries and other subjects collected and reported to the country within a short space of time."

Nevertheless, there has been a constant effort at improvement, especially beginning with the census for 1880, for the collection of general statistics by enumerators and supervisors; the withdrawing of schedules of manufactures from the enumerators and the substitution of special agents in the more important manufacturing centers; and the employment of experts in making special investigations then introduced has been continued and extended, so that whereas in 1880 there were 279 cities withdrawn, 373 special agents employed to collect these statistics and nine expert agents to conduct statistical investigations, in 1890 there were 1,042 cities withdrawn, 1,383 special agents and assistant agents, and thirteen expert special agents, and in 1900 there were 1,340 cities withdrawn, 1,891 special agents employed and twenty-two expert agents engaged in researches.

The Act of March 3, 1899, under which the twelfth census was conducted, is regarded as being decidedly the best law that has ever been enacted for the taking of a census. By it the executive and statistical branches of the work were so sharply defined as to make the person in charge of each inquiry responsible for lack of method or tardiness in securing results. Under the Act there was appointed a Director who had the general charge of the administration, an Assistant Director, who is a trained statistician, to whom was assigned the general oversight of the various statisticians employed in the Bureau; five Chief Statisticians, to each of whom a certain line of inquiry was assigned, and for the manner and method of execution of which he was held responsible; Expert Special Agents and Special Agents as required; and five Expert Chiefs of Division besides the necessary clerical force. The Act creating the Bureau, for the first time in the history of census legislation, prescribed absolutely a time limit, namely, two years, for taking the statistics, arranging and analyzing them, and publishing the results for the census topics proper; population, vital statistics, agriculture and manufactures. These final volumes by this law constitute the "census reports" for the twelfth census. On the completion of this census the Act provided that the Census Bureau should then collect statistics relating to special classes, including the insane, feeble-minded, deaf, dumb and blind; to crime, pauperism and benevolence; to deaths and births in registration areas; to social statistics of cities; to public indebtedness, valuation, taxation and expenditures; to religious bodies; to electric light and power, telephone and telegraph business; to transportation by water, express business and street railways; and to mines, mining and minerals, it being prescribed that the reports relative to mines, mining and minerals should be published on or before July 1, 1903, and that the reports on all topics other than population, vital statistics, agriculture and manufactures are to be styled special reports. The mere recounting of these topics indicates how greatly the scope of the census has become enlarged from the simple enumeration of population as required by the Constitution.

This tendency to extend the inquiries has been observed from the beginning, for the Act under which the first census was taken called not only for an enumeration of all inhabitants (excluding Indians not taxed), but also required the marshals to distinguish the sex and color of free persons and to separate the free males of sixteen years and upwards from those under that age; the latter requirement being undoubtedly for the purpose of ascertaining the military and industrial strength of the country. An effort to make the census for 1800 the vehicle for ascertaining sundry facts highly interesting and important to society was set on foot previous to the enactment of the law under which that census was taken. Two memorials to that end were submitted to Congress. One from the American Philosophical Society was signed by Thomas Jefferson as its president, and begged leave to submit to the wisdom of the legislature the expediency of requiring, in addition to the table of population, as in the former Act, "others presenting a more detailed view of the inhabitants of the United States under several different aspects." The second, from the Connecticut Academy of Arts and Sciences, signed by Timothy Dwight, its president, recited the fact that it was the belief of the memorialists "that to present and to future generations it will be highly gratifying to observe the progress of population in this country, and to be able to trace the proportion of its increase from native Americans and from foreigners immigrating at successive periods; to observe the progress or decline of various occupations; the effects of population, luxury, mechanic arts, the cultivation of lands, and the draining of marshes on the health and longevity of the citizens of the United States;" and to this end each asked that data be taken and classified so as to show the age, sex and condition of the inhabitants, their nativity, their occupations or professions and their location. Little immediate notice seems to have been paid to these memorials, though the statistics taken were extended to include five age-classes; but in the following census of 1810, as before stated, the inquiries were enlarged to include statistics of manufacture, and with the machinery at hand and the precedent established, the statistician, the economist, the sociologist, the humanitarian, the publicist, the capitalist, the man of science, all who sought information regarding peoples and their activities on a large scale, have sought to put this agency to further uses, especially since 1840, until it has come to embrace an enormously wide range of topics. This extension has been seriously criticised. It has been said of the periodical census that, "as it has widened, it has weakened. More has been put upon the enumerator than he could well carry. His attention has been distracted by the multiplicity of objects presented, while the great number of inquiries has also perplexed and irritated the body of citizens." It has been charged that the added topics of inquiries exceeded the constitutional requirements; that the results are below the truth, and that they are necessarily incorrect because of the failure to complete the enumeration in a single day.

Taking these criticisms up in the reverse order, it may fairly be claimed that the criticism as to the length of time applies primarily only to the statistics of population. With the census of manufactures the conditions are such that it has no force; its data refer to a definite period and not to a date (as, for instance, in the twelfth census to the year ending June 1, 1900); its returns may be compiled from the records already made and existing in the factories; and changes in the number of establishments before or after that initial and final date cannot affect the established result.

As to the results presented being below the true ones, it is to be said that there seems to exist in man a natural inclination to overestimate and to magnify. According to Walker, the results of the first census of population, taken in 1790, like those of the first British census taken in 1801, was a great disappointment to the people of each of these countries, and dissatisfaction at the methods of enumeration was loudly expressed. Even Mr. Jefferson, as Secretary of State, when sending copies of the published tables abroad, was careful to impress it on the minds of his correspondents that the returns fell far short of the truth. The results of later censuses, however, established the substantial accuracy of the first enumeration, and showed that the dissatisfaction felt at the time was but the inevitable disappointment of over-strained anticipations. "To count," says Dr. Johnson, "is a modern practice; the ancient method was to guess; and where numbers are guessed, they are always magnified."

As to the criticism that any inquiry beyond the mere enumeration of population exceeds the constitutional requirements of a census, it may be admitted that this is true; but the constitution dealt in this particular only with the primary necessity. It did not prohibit further inquiries, and the extension of this system of taking a national inventory has been justified by the results.

The criticism as to the burden put upon the enumerator and the weakening of the system through overloading has been well taken. It is less pertinent since the custom of detailing special agents to collect manufacturing and other statistics, and expert special agents to conduct special investigations, has come into vogue, and the perplexing and irritation of the people has also been lessened by the employment of agents who more clearly understood the nature, objects and relations of the interrogatories and so were able to properly explain them when the queries were not clearly understood.

All these criticisms were known and appreciated when the law, under which the census of 1900 was taken, was enacted and the division of manufactures organized, and provision was made for avoiding the errors pointed out so far as was possible. One fact that was especially impressed on the minds of those who planned the work was the futility of making the inquiries very detailed and minute. The experience with the electrical industries for 1890, alluded to above, was a striking example of this kind, as this elaborately planned investigation came to naught.

The Census Office, established under the Act of March 3, 1899, was organized by the appointment of Hon. William R. Merriam as Director; Dr. Frederick H. Wines, Assistant Director; William C. Hunt, Chief Statistician for Population; William S. King, Chief Statistician for Vital Statistics; S. N. D. North, Chief Statistician for Manufactures; LeGrand Powers, Chief Statistician for Agriculture; Walter F. Willcox, Chief Statistician for Methods and Results; and Henry Gannett, Geographer. Each of these chiefs was chosen for his well-known ability in handling the particular subject assigned him, and each had a reputation for capacity and thoroughness in his special line of inquiry. Mr. North, the Chief Statistician for Manufactures, had long been known as a student and authority on statistics of manufacture. Beginning on the staff of the Utica *Morning Herald*, in 1869, he rose to the editorship of the Albany *Express*, which he resigned in 1888 to accept the position of Secretary of the National Association of Wool Manufacturers and editor of its Bulletin. He served as expert special agent in the eleventh census; as an efficient member of the Industrial Commission appointed by President McKinley, and in other public capacities. His experience and reputation warranted the belief that the results achieved in this census of manufacture would prove to be of great value and to possess unusual reliability and fullness, and these expectations have been fully realized.

In the organization of the division the first effort was to secure, so far as possible, a clerical staff of experienced men. This was by no means a simple matter, as, notwithstanding repeated protests, Congress has always enacted legislation as if it regarded the census work as a temporary undertaking, and it has permitted the force assembled for each census, after it has become trained and experienced, to be widely scattered and absorbed elsewhere as soon as the work was closed. Among the efforts made to prevent the recurrence of this practice were those of the American Economic Association and the American Statistical Association, which, through a joint committee in 1896, presented a memorial to Congress calling attention to the importance of at once establishing a permanent and independent census office. The memorialists state that in doing so they are actuated by an earnest desire for the scientific development of statistics in the United States; that they represent learned societies whose members come, through their professional duties, in constant, almost daily, contact with the point of view of those who use statistics, and that it is in the general interest that they plead for methods of census administration which would tend to increase its efficiency and heighten the value of its results. And in this connection the memorialists further say:

"In many departments of statistical work the publications of the United States Government occupy an honorable place. Through the liberal provision which has been made in the past for statistical inquiry, the United States has been able to contribute substantially to the development of statistical methods and to the extension of statistical research. But the work of the Government is uneven and sometimes fails to reach the highest standard. This is true of the census, the largest statistical undertaking of the Government, upon which money and effort are so generously lavished. There cannot be a moment's doubt that this work should be brought to the highest possible standard of statistical excellence.

"It is no reproach to the census as a whole, nor to the gentlemen who have administered the census office, to say that in many respects the census reports are unsatisfactory to us as students of statistics and to the people of the United States.

"We allude particularly to the attempt to cover too much ground, the enormous cost of the undertaking, and the delay in the publication of the completed tabular results. These criticisms all grow out of the legislation under which the census is taken. The defects of our present organization may be summarized under the following heads:

"(1) *Accumulation of inquiries at the same period of time.*

"(2) *The lack of continuity in the census work.*

"(3) *The haste with which the whole machinery of the census is placed in motion.*

* * * * * *

"The permanent and independent census furnishes the best guarantees for improvements in statistical work, if established under proper conditions. But it would be a grave misforture to postpone the organization of such a bureau until shortly before the time for taking the next census. We cannot urge too strongly that consideration be given at an early date to this question. If, as it should, the census of 1900 is to be an advance over those of preceding years, thorough preparation for the work is indispensable. We are convinced that the gravest difficulty which has hitherto impeded the work of the census is the haste with which it has been planned and executed.

"It is not alone in the interest of statistical science, but in the interest of the public, which has an undoubted right to the most accurate and prompt information which the census office can furnish, that we urge the adoption of a measure which will attain this end and mark distinct progress in the statistical work of the Government."

Notwithstanding this earnest memorial and this wise advice, nothing was then done by Congress, and the twelfth census, like its predecessors, was organized on a temporary basis; but wiser counsels have since prevailed, and by Act of Congress of March 6, 1902, the Census Office was put upon a permanent footing from July 1, 1902, and the evils which have been charged to a temporary organization must henceforth be eliminated. Fortunately, owing to their superior character, a fair number of the trained employees of the previous temporary censuses have, when the work was closed, been transferred to other departments of the Government, and from such men a nucleus for each new census has been formed.

With such a nucleus to preserve the traditions, to which clerks selected by examination was added, the Division of Manufactures for the census of 1900 began the classification of industries, drafting of schedules, securing addresses of establishments and in general making preparation for the field work. In making the classification and in drafting the schedules every effort was made, while complying with the law of 1899, to adhere to the forms used in preceding censuses so far as possible, as all changes of classification are to be regretted since they made it difficult and at times impossible to trace the development of a given industry through successive census periods. It is true, of course, that certain changes are unavoidable because of radical modifications which take place in the various processes of manufacture; but it is safe to say that the majority of such changes as have been made in the past have not been due to this cause, but to repeated changes in the office force with whose chief officers this question of classification has rested. By the system adopted the industries were divided into 354 different varieties and these were combined into fifteen groups. The first step is in accordance with that followed in the census of 1890, though there were then 369 varieties recognized. Such a classification, although necessary and proper, is not sufficient to present a clear, intelligible and scientific view of the general character and distribution of our manufacturing industries. It results in an alphabetical arrangement, which may be described as a statistical conglomerate, through which the student has to pick his way, making his own combination as he goes.

To remedy this defect the twelfth census has also brought the industries of the country together in fifteen grand groups. In making this generic grouping the effort has been to follow lines distinct and well recognized in common practice. The hand trades are set off into one group, and the true manufacturing industries are collected into groups distinguished either by the chief components employed as raw material, or by similarity in the use of the products, or by both. This grouping is found to embrace all but a comparatively small number of industries, which are classed together as an independent group.

Statistics, like other branches of investigation, reaches the point where it may properly be called scientific, only when the fundamental resemblances of individual phenomena are noticed, for then the former haphazard knowledge becomes organized knowledge. By the scheme adopted in this census the 354 industries correspond, in a measure, to the "species" of natural history, while the fifteen great groups of industries are analogous to the "genera," the whole making the great "order" of manufacturing industry. Thus viewed, we have as the subject of investigation the great order of manufacturing industry, made up of the fifteen genera or group of industries, each utilizing a common material or subserving a common purpose. These family groups ramify into the 354 various industries, each in turn being made up of the individual establishments.

The introduction of this system of grouping and its application to the statistics of this census, while rendering these readily available, in no measure prevents ready comparison with the available statistics of previous censuses; for, having formulated a grouping of the various industries which shows their relations and interdependence, it becomes possible so to apply the rule of selection and aggregation to the results of prior censuses as to show comparative statistics for each of the groups of industries.

Prior to the commencement of the field work a card catalogue was prepared of all establishments of productive industry throughout the United States of which a record could be found. In this work city directories were utilized, supplemented by trade directories, the reports of factory inspectors, the lists of commercial agencies, records of technical journals and notices of new factories supplied by newspaper-clipping bureaus.

The cards thus prepared for each of the greater cities were numbered and forwarded to the chief special agent of each city, who was required to return every card marked to show whether a schedule had been secured for the establishment, and if not, the reason why, as "burned,' "removed," "not manufacturers," etc. The cards for the smaller cities were retained at the office, and the schedules as received were checked upon them. When the local agent announced his work complete, he received from the office transcripts of all cards for which schedules had not been received, and was required to furnish the missing returns or supply a satisfactory reason why they could not be obtained. In this way the office possessed a complete check upon the work of every special agent, and was able to secure a more thorough and satisfactory canvass than had ever before been obtained.

[*To be concluded.*]

Mining and Metallurgical Section.

Stated Meeting, held March 28, 1903.

A Study of Alloys Suitable for Bearing Purposes.

By G. H. Clamer.

Among the many problems presented to motive-power officials, there remains one of special interest which has lacked the scientific research which is its due. I refer to the metallic alloys suitable for journal brasses. There is no more important subject for investigation. The successful operation of rolling-stock in a great measure is dependent upon the bearings.

Much uncertainty exists as to what is the best constituted alloy for this particular service. Hundreds of formulas have been recommended, and ninety-nine out of each hundred founded upon the grand principle of "guess."

At first glance it may appear an almost hopeless task to even surmise which alloy is best constituted for such service; but upon closer examination we find that but few metals are available. They are as follows:

Copper, tin, lead, zinc, antimony.

It is true that other metals and metalloids may be introduced in varying small proportions, either with or without some material advantages, but the above five metals constitute the basis which may be used for the so-called anti-friction alloys. The combinations of the above metals, which to-day figure in service for this purpose, may be classed under two heads:

(1) White metals.
(2) Bronzes.

I. WHITE METALS.

(1) Lead, antimony.
(2) Lead, antimony, tin.
(3) Tin and antimony.
(4) Tin, antimony, copper.
(5) Tin, antimony, copper, lead.
(6) Zinc, tin, copper.
(7) Zinc, tin, antimony.
(8) Zinc, tin, antimony, copper.

II. BRONZES.

(1) Copper and tin.
(2) Copper, tin and lead.
(3) Copper, tin, lead and zinc.
(4) Copper, tin, zinc.
(5) Copper, zinc, lead.

The multiplicity of formulas recommended for journal brasses is evidenced by the table appended hereto, which is compiled by G. Charpy and published in his valuable treatise on the "Study of White Metals Called Antifriction."

I will confine myself in this paper more particularly to the study of alloys suitable for railway journal bearings, as this is perhaps the most important application of such alloys; furthermore, what applies here is in a certain sense true of all other applications.

It will no doubt be interesting to have before us the essential points to be considered in this connection:

(1) Composition.
(2) Structure.
(3) Friction.
(4) Temperature of running.
(5) Wear on bearing.
(6) Wear on journal.
(7) Compressive strength.
(8) Cost.

It is an utter impossibility to have one alloy reach the pinnacle of perfection in all the above requirements, as I shall later demonstrate; for example, the metal showing the slowest rate of wear may have the highest coefficient of friction, or the metal with the lowest coefficient of friction may have the greatest rate of wear, etc.

If it were possible to reach mechanical perfection in the adjustment of bearings it would be of little consequence what alloy or metal were used, providing the same had sufficient strength to support the load without deformation. If perfect adjustment were possible we would have at no time metal in contact with metal, but simply metal in contact with oil, the friction would be essentially fluid friction and abrasion due only to the wear of fluid against solid. But, unhappily, such a state of perfection can scarcely be reached, and never will be reached in railway journal bearings, where end thrusts, lateral motion, reversal of direction of motion, etc., are continually encountered. Such being the existing state of affairs, the above tabulated qualifications must be studied and each balanced against the other according to its importance.

First and foremost qualification is that the alloy have the best composition, all things considered, to make the bearings—on this depends all the following essentials.

(2) On the composition in a great measure depends the structure. It is true that heat treatment and certain manipulation may affect the structure of the same compositions, but this effect is more particularly upon the size of crystals, etc. What is here meant by structure is the characteristic structure of a certain combination of metals; for example, the binary alloy, antimony and lead. This consists of crystallites of lead imbedded in a matrix of eutectic if the percentage of antimony be below thirteen, and, if above thirteen, consists of eutectic and free crystals of antimony. It has been shown that a successful bearing alloy must consist of at least two structural constituents—one hard constituent to support the load, and one soft constituent to act as a plastic support for the harder grains. Generally speaking, the harder the surfaces in contact, the lower the coefficient of friction, and the higher the pressure under which "gripment" takes place.

It would seem for this reason, the harder our bearing alloy, the better. It was with this idea in mind that alloys of copper and tin were so extensively used in the early days of railroading. A hard unyielding alloy for successful operation must, however, be in perfect adjustment, a state of affairs unattainable in the operation of rolling-stock. In order to obtain a proper adjustment of bearings when first applied in service, Mr. Hopkins many years ago introduced his lead-lined bearing. The practice of lining bearings has now become almost universal in this country. But notwithstanding that the bearing by this method obtains a good seat on the journal, the adjustment is constantly disturbed, and the bearing proper must have a certain plasticity of its own to avoid heating when called into service to support the load.

In order to secure this plasticity, lead was introduced into the copper and tin alloy, and with excellent results, but this I will treat more fully later.

Much can be said regarding the causes of excessive heating of journal-bearings, but this is a subject which has been thrashed and rethrashed so often, that I will not attempt to go into the matter any further than to discuss those causes which are directly due to the brass itself.

(3) The third consideration in connection with our determination of the most suitable alloy is friction. Friction is dependent upon the composition and structure of the alloy. As stated, generally speaking, the harder the metals in contact, the lower the coefficient of friction; thus the class of bronzes have a lower coefficient of friction than the babbitt or white metals. At the same time, the harder the metal, the greater the liability of heating, because of the absence of plasticity (the property a metal has of molding itself to irregularities on the journal, and the consequent maintenance of a large area to carry the load). A hard unyielding metal under the above conditions will cause a concentration of load upon one or more high spots, and so cause an abnormal pressure per square inch on such areas, with the result that rapid abrasion and heating soon result. A hard unyielding bearing is a theoretical delusion, much to be desired, but impracticable of application.

Structure of the alloy plays an important part, as hard spots caused by oxidation, etc., frequently cause an irritation of the journal with a simultaneous production of abnormal friction and temperature.

(4) Temperature of running is of importance for determination, in so much that the amount of oil consumed is greater, the higher the temperature, but at the same time the lower the friction, providing the bearing is running under normal conditions. This is true only when comparing the same bearings under different temperatures, because the higher temperature may be caused by increased friction.

Generally speaking, the bronzes under the same conditions of pressure and speed will operate at a lower temperature than the softer metals, all things being equal.

(5) Wear of bearing. It is quite remarkable the relation existing between composition and wear. This presents a wide field for research—a field almost unexplored. High-priced compositions are being used, which have but little resistance to wear compared with cheaper compositions, and low-priced alloys are in service that are not cheap at any price. But very little data is to be had on this score, for the reason that such tests in service require a great deal of time, and a satisfactory laboratory machine has not until recently been designed. A machine which the writer has used for the past two years has given good satisfaction, and will be described shortly.

(6) Wear on journal. Composition of the bearing has a decided effect upon the wear of the journal; but whether the difference in the rate of wear is due directly to the composition is a disputed point—no positive proof to this effect is attainable. It is generally conceded that the soft metal bearings cause a marked decrease in the life of journals. Now, as to whether this is due to the imbedding of grit on the bearing surface, with the consequent formation of a lap, or to the fact that the metal itself has a dragging nature, I am not prepared to say. In a recent paper by Mr. David Van Alstine, some statistics were given on the life of journals, which I think will be interesting here.

(1) *Tender Axles* for ½-inch wear—490,000 miles—5 per cent. removed for collar wear.

(2) *Engine Truck Axles* for ½-inch wear—245,000 miles.

(3) *Driving Axles* for ½-inch wear—476,800 miles.

(4) *Freight Car Axles*—274,000 miles—29 per cent. removed on account worn collars.

(5) *Passenger Car Axles*—504,000 miles—94 per cent. removed on account collar wear.

Mr. Van Alstine attributes the low mileage shown by English truck axles as due to the fact that these are babbitted brasses.

Driving axles, he declares, have a tendency to wear tapering and hollow. This he attributes to the uneven distribution of dirt in the packing. Uneven wear is caused in many cases, however, by the use of babbitt strips across the bearing surface; the tendency to wear hollow, at any rate, can be traced to this cause. Observations to this effect have been made by a number of prominent railroad men and recited to the writer. In one instance the strips were set according to the usual practice, only over a portion of the surface as shown in *Fig. 1*, which is a view looking down on an inverted brass.

The result of the uneven wear on the journal was that a depressed area plainly marked the increased rate of wear due to the babbitt strips. *Fig. 2* is a slightly exaggerated view of the appearance of such an axle.

To remedy this defect the babbitt strips were allowed to extend across the entire surface; the result was an even but proportionately greater rate of wear. Owing to the above conditions prevailing and the fact that babbitt often becomes so heated as to melt and run out, causing frequently serious trouble, is a good argument for the abandonment of such practice.

FIG. I

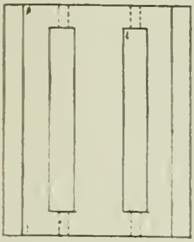


FIG. II

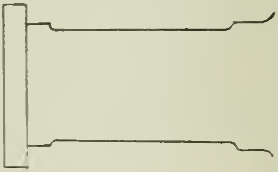
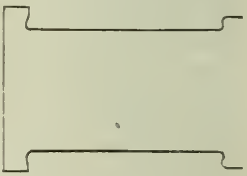


FIG. III



The low mileage of freight-car as compared with passenger-car axles is attributed to the fact that they receive less attention, which is quite plausible, ill-fitting lids and dust-guards allowing more dirt to enter the box and cause abrasion. It is surprising to learn that 94 per cent. of the passenger-car axles are removed on account of worn collars. This state of affairs may, without much hesitation, be laid to the lead lining of brasses lapping out the fillets. That such is the case is an undisputed fact, and has come to the notice of all observing motive-power officials. Fillets are not only worn to a right-angle, but are often cut in as is shown in *Fig. 3*.

Compressive Strength.—A test of the compressive strength of alloys intended for use as bearings is of importance in indicating—

(1) If the alloy is hard enough to support the load without deformation.

(2) If the alloy is brittle and will split under effects of pressure.

(3) If it is sufficiently plastic to reasonably suppose it will run cool under aggravated conditions.

Now, having briefly discussed the qualification of the bearing metal, let us take up the various combinations of metals as previously classified and study their characteristics.

(1) LEAD AND ANTIMONY.

These metals will alloy in any proportion, with increase of antimony the alloy becoming harder and more brittle. The combination of these two metals, however, which alone is exempt from segregation, is that of the eutectic mixture, which according to various authorities has been found to be approximately: lead 87 per cent. and antimony 13 per cent. Alloys with less than 13 per cent. show, upon microscopic examination, to consist of dendrites of pure lead imbedded in a matrix of eutectic. The structure of the alloy with the eutectic composition shows no segregated metals or alloys, and has a laminated structure characteristic of all eutectics consisting of laminæ of lead and laminæ of antimony.

With above 13 per cent. of antimony, free crystals of antimony appear, and, if the alloy is allowed to cool slowly, they rise to the surface, owing to the very low specific gravity, namely, 6·5, as compared with the specific gravity of the eutectic, which is 10·48.

The melting-points, as given by Stead, are for the segregated antimony about 615° C., and for the eutectic 247° C. It will be noted that the temperature of the eutectic is 78° below the conceded melting-point of lead—the most fusible constituent; therefore in an alloy below 13 per cent. antimony, the lead crystallizes out of the still fusible eutectic in the form of so-called and well-known "Fir Tree" lead.

Alloys containing 10 per cent. antimony show upon the surface of a slowly cooled ingot the eutectic spherules and lead crystals.

Alloys containing less than 6 per cent. antimony show only lead crystals upon the surface, owing to the predominance of those which solidify over the eutectic.

According to Charpy, an antifrictional alloy should consist of hard grains, which carry the load imbedded in a matrix of plastic material, to give it the property of molding itself to the journal and its irregularities without undue heating. Such a condition is met in the alloys above the eutectic composition; but with increasing antimony the alloys become more brittle, and above 25 per cent. are unsafe in service for this reason.

Charpy further claims that alloys between 15 per cent. and 25 per cent. are best constituted for bearing purposes. I cannot quite agree with this, however, as the alloys containing below 13 per cent. antimony can likewise be said to consist of hard grains (the eutectic imbedded in lead), and it has been my experience that, although the friction may be higher in such alloys, the wear is greatly diminished, and where pressures are light, causing no deformation, this is a great advantage. I have seen many instances in service where alloys between 15 per cent. and 25 per cent. were greatly inferior to alloys between 8 per cent. and 12 per cent., owing to their frequent renewal due to wear.

It will perhaps be interesting to hear that the Pennsylvania Railroad Company, at the suggestion of Dr. Dudley, their chemist, have adopted the 13 per cent. antimonial lead alloy as a filling metal for bearings in order to obtain the best results.

The appended table compiled by Charpy illustrates the above facts, and these results in a general way are confirmed by our own work on the subject, viz.: that lead is the best wear-resisting metal known, and that with increasing antimony, or increasing hardness and brittleness, the wear becomes more marked. This is due to the splitting up of the harder particles.

The friction, as we may naturally expect, becomes less with increase of antimony, and the temperature of running likewise diminished when running under normal conditions; but the harder the alloy, the more difficulty is experienced in bringing it primarily to a perfect bearing, and the greater the liability of heating through aggravated conditions. The wear on the journal one would naturally expect to be decreased with increasing hardness; but this journal wear is in all probability not due so much to the alloy directly as it is to the fact that the softer metals collect grit, principally from the small particles of steel from the worn journal, and, acting as a lap, causing rapid wear. With the harder metals these particles are worked out without becoming imbedded.

The cost of the above alloy is the least which can be produced. It can be used in many services where higher-priced alloys are being relied upon mainly for their high cost. It is one of the greatest extravagances of large industrial establishments to use goods which are too good for certain uses, and even perhaps unsuited, under the supposition that they must be good because they paid a good price for them. This fact has no greater exemplification than in the purchase of babbitt metal, and is due to the great uncertainty which exists, not only among consumers, but among manufacturers, many of whom carry on their business much the same as the patent-medicine man.

(2) LEAD, ANTIMONY AND TIN.

I do not wish it understood that antimony-lead is the cheapest alloy to use under all circumstances; not so, for when high pressures are to be encountered, tin is a very desirable adjunct. Tin imparts to the lead-antimony alloy rigidity and hardness without increasing brittleness, and can produce alloys of sufficient compressive strength for nearly all uses. The structure of a triple alloy of this nature is quite complicated, and not yet definitely defined.

Besides the existence of various metals in the free state, or in solid solution according to the proportions in which they exist, there is a distinct chemical combination SbSn. The introduction of tin into the finely crystalline antimonial lead of commerce gives it a coarser grain, due to the formation, no doubt, of the cubical crystals of the above-mentioned chemical combination SbSn. The cost of the alloy increases with increase of tin; but for certain uses, where insufficient compressive strength cannot be gotten by antimony, because of its accompanying brittleness, it is indispensable, and will answer in nearly every case where the tin basis babbitts are used.

(3) TIN AND ANTIMONY.

This alloy, with 5 per cent. antimony, is shown to consist of free tin and a matrix of tin and antimony, probably of the formula SbSn or $SbSn_2$, as claimed by some investigators. The same is true of alloys containing up to 45 per cent. antimony, when the scattered crystals previously seen are brought closer and closer together, as in the lead-antimony alloy, until they are in close contact with each other, and probably have formed the compound Sb_2Sn_2. Tin and antimony are seldom used alone as bearing alloys, but are extensively used for so-called Brittania ware, and in equal proportions for valve seats, etc.

(4) TIN, ANTIMONY AND COPPER.

This combination is what is known as genuine babbitt, after its inventor, Isaac Babbitt, who presumably was the first man to conceive the idea of lining bearings with fusible metal. The formula, for no arbitrary reason, which he recommended is as follows:

Tin	89·1
Antimony	7·4
Copper	3·7

This formula is still considered the standard of excellence in the trade, and has been adopted by many of the leading railroads, the United States Government and many industrial establishments. It is used in the majority of cases where cheaper composition would do equally as well.

According to Behrens and Bauche, who have made extensive examination of this triple alloy, it is made up of rectangular crystals of an alloy of tin and antimony, a whitish bronze forming radial clusters or brittle rods composed of hexagonal flakes, the mother liquor or matrix being nearly pure tin. The cuboidal crystals are evidently 9 per cent. tin and 1 per cent. antimony, and the rods of whitish bronze 9 per cent. tin and 1 per cent. copper. This is the most costly of all bearing alloys because of the high content of tin.

(5) TIN-ANTIMONY-LEAD-COPPER.

This quadruple combination of metals I will not venture to describe, as it would no doubt take years of study to fathom the complicity of the metallic combinations here represented. Suffice it to say that lead, although of itself a soft metal, renders this alloy, when added in but small proportions, harder, stiffer, more easily melted and superior in every way to the alloy without it, and yet consumers will raise their hands in horror when a trifling percentage of lead is found in their genuine babbitt. This is one of the instances where cheapening of the product is beneficial.

The foregoing represents the more important combinations of alloys of tin and lead basis. These are of far more importance in the arts than the white metals, the main portion or basis of which is zinc.

At various times new combinations of zinc have been proposed, but so far as my knowledge goes, they have not come into popular use for two reasons. First, because of the great tendency of zinc to adhere to iron when even slightly heated. What is technically known as galvanizing the journal is effected under these conditions. Second, because of the brittleness produced under the effects of heat, such as is produced by friction when lubrication is interfered with and consequent danger of breakage. I will not discuss the various combinations of zinc separately, because, as I have already said, they present but little practical importance.

BRONZES.

Bronze is the term which originally was applied to alloys of copper and tin as distinguished from alloys of copper and

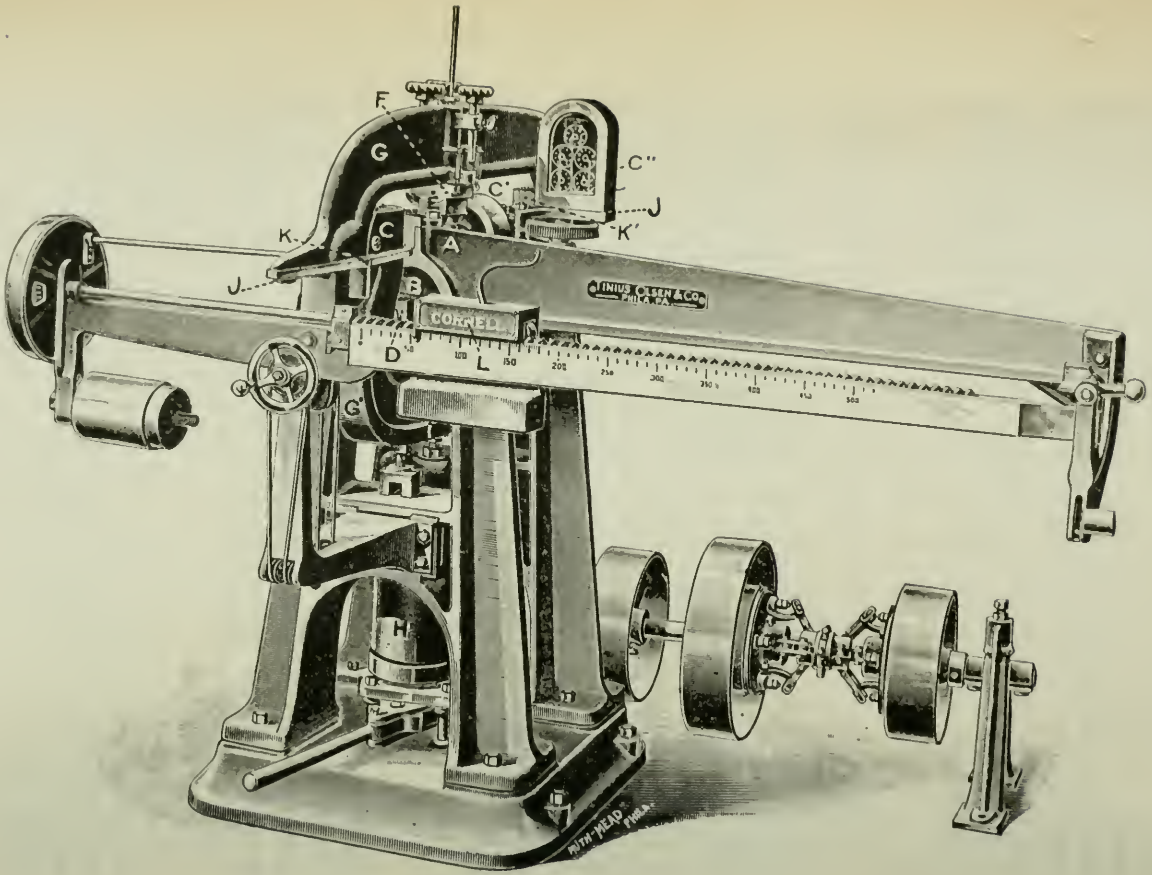


FIG. 4.—Professor Carpenter's testing machine. (Built by Tinius Olsen, Philadelphia.)

zinc; but gradually the term "bronze" has become applied to nearly all copper alloys containing not only tin, but lead, zinc, etc., and no sharp lines of demarcation exist between the two.

The tests I am about to describe were conducted on a testing machine designed by Professor Carpenter, of Cornell University, and built by Olsen, of this city. (*Fig. 4.*)

It consists of a journal *A*, which revolves on the large cast-iron wheel *B*, and held in position by the bearings *C*, *C′*, *C″*. The object of the wheel *B*, which revolves on the bearings *D* and *D′* is to take the pressure and thus relieve the bearings *C*, *C′*, *C″*, which would otherwise become heated and cause erroneous readings. The test bearing *E* is held in contact with the journal by means of the ball-and-socket joint *F*—the socket being on the bearing, and the ball on the adjustment screw supported in the knife edge lever *G* and *G′*. The load is put on the bearing by means of spring *H*, which pulls downward on knife edge *I*, and this in turn on the knife edges *J* and *J′*, and these against smaller springs *K* and *K′*. The pressure is recorded in pounds. The speed indicator and counter records the number of revolutions. The arm attached to lever *G*, by means of the screw-operated weight *L*, indicates the friction in pounds, or in other words balances the pull due to friction. A thermometer is placed in the hole in the bearing to record the temperature. This machine is compact and I have found it quite satisfactory.

The test bar I have adopted is 3½ inches long and ½ inch wide. This can be weighed on a delicate chemical balance, and from 100,000 to 500,000 revolutions will give a very perceptible wear. The data thus obtained:

(1) Loss of metal by wear obtained by weighing before and after test.

(2) Friction in pounds.

(3) Temperature of running.

The constants are:

Area of contact.

Pressure per square inch.

Kind of lubrication.

Method of lubrication.

The most satisfactory method of lubrication thus far found has been that of ordinary car lubrication, viz.: by means of waste held to the under side of the journal.

This machine has overcome many of the defects of the old Thurston machine and various others which are largely used.

Each of the alloys tested was subjected to chemical analysis and microscopic examination to obtain as complete a knowledge as possible of the alloys under consideration.

The first series studied is that of copper and tin.

COPPER AND TIN.

This, according to our general conception of the word, is a bronze only when the copper content exceeds that of the tin. According to the proportions in which the metals exist, it has widely different properties. In general, the tin hardens when present up to proportions of 30 per cent., or perhaps a little over, and when this limit is exceeded, it takes on more and more the nature of tin until pure tin is reached. From a scientific point of view this alloy is one of the most interesting and has attracted the attention of many investigators, who have spent years of study on it, to learn its various properties and explain its constitution. The investigators are Kunzel, Thurston, Charpy, Haycock, Neville and others.

The alloys which interest us most, however, are those which are so constituted as to be adapted for bearing purposes. These would be said to contain from 3 to 15 per cent. tin, and from 85 to 97 per cent. copper. The alloy of tin containing smaller percentage of copper is often used as a babbitt metal, but this comes under the class of white metals, which I have already discussed. Bronze containing above 15 per cent. of tin has been recommended at various times for bearings owing to its hardness, but very unwisely, for such a bearing assumes mechanical perfection and perfect lubrication. It has no plasticity of its own, and immediately as the oil film is interrupted rapid abrasion and gripment take place, with hot boxes as the result. The very erroneous idea is still held by many, that to resist wear and run with the least possible friction a bearing alloy must be as hard as possible. It is true that hard bodies in contact move with less friction than soft ones; but the alloy which is the least possible to heat and cause trouble is the one which will stand the greatest amount of ill use; by this I mean an alloy which has sufficient plasticity to adapt itself to the irregularities of service without undue wear. The enthusiasts of hard bearings have even gone so far as to try glass for this purpose, and whereas this substance may give satisfaction on perfectly adjusted light spindles, for example the jewel bearings of a watch, we can readily imagine what would be the consequences if such a trial was made on locomotive or car journal bearings. It is for the foregoing reasons that I have limited the useful bearing alloys of copper and tin to those containing less than 15 per cent. tin, and began my investigation from this point.

The alloys of copper and tin I will treat in rather more detail, owing to the bearing which they have on the alloys which follow, rather than for their actual usefulness for the service.

These alloys were used extensively some twenty or twenty-five years ago, and were indeed considered the standard for railroad and machinery bearings. The old alloy, known as "Cannon Bronze," containing 7 parts copper and 1 part tin, is still being specified by some few unprogressive railroad men and machinery builders.

Copper 85 per cent., Tin 15 per cent.—Microscopic examination shows this alloy to be made up of chemically combined copper $SnCu_3$, dendrites of pure copper, and a large area of eutectic mixture, 73 per cent. copper, 27 per cent. tin, as given by several authorities.

The tests on the machine show the following:

Friction in pounds	13
Temperature above room, degrees F.	50
Wear, in grams	·2800

The friction, as naturally expected, is lower than that of any of the following alloys which were tested, they being all softer than the above. The temperature of running, being a factor of the friction, is likewise less. The wear, however, is greatest of all, no doubt due to the large amount of hard brittle eutectic present (copper 73, tin 27).

Copper 90 per cent., Tin 10 per cent.—This alloy has the same general structure as the alloy of 15 per cent. tin, but differs in the greater amount of free copper and lesser amount of eutectic which it contains.

Machine tests:

Friction in pounds	13
Temperature above room, degrees F.	51
Wear, in grams	·1768

The friction was practically the same, temperature little higher than the foregoing, but the rate of wear slower, owing to the smaller amount of eutectic present, and its consequent softness.

Copper 95 per cent., Tin 5 per cent.—This alloy contains, beside the $SnCu_3$, large amounts of free copper, and but small amount of eutectic, especially if the alloy is quickly cooled.

Machine tests:

Friction in pounds	14
Temperature above room, degrees F.	52
Wear, in grams	·0776

Friction and temperature are here again higher, and the rate of wear greatly diminished.

To Dr. C. B. Dudley, chemist of P. R. R. Co., is due the credit of having done more for the establishment of good sound knowledge on the subject of bearing-bronzes than any one else. Dr. Dudley, in a paper which he read before the Franklin Institute in 1892, showed the relation existing between the tin and lead content of the copper alloy, and his determinations were founded on actual practical tests. In their relation to the tin content, are summed up in his own words, as follows: "The rate of wear diminishes with the diminution of tin." These determinations, it will be noted, are confirmed by my own work on the subject, and gives us a starting point on which we have based our knowledge for the production of a very efficient bronze for bearing purposes, presently to be described.

COPPER, TIN AND LEAD.

The copper, tin and lead alloy is now recognized the standard bearing-bronze, and in the above-mentioned paper the fact was clearly established that lead introduced into the copper-tin alloy was a decided advantage; first, because the bearing containing lead was less liable to heat, under the same state of lubrication, etc.; and, second, the rate of wear was greatly diminished. Experiments were made in service which clearly demonstrated the above facts. It will no doubt be interesting to note the following table, which represents these results in classified form:

Metal Tested.	Composition.					
	Copper.	Tin.	Lead.	Phosphorus.	Arsenic.	Relative Wear.
Phosphor-bronze, standard	79·70	10	9·60	·80	...	1·00
Ordinary bronze	87·50	12·50	...	...	...	1·49
Arsenic bronze, "A"	89·20	10	...	...	·80	1·42
" " "B"	82·20	10	7·00	...	·80	1·15
" " "C"	79·70	10	9·50	...	·80	1·01
Bronze, "K"	77·00	10·50	12·50	...	...	·92
	77·00	8·00	15·00	...	...	·86

Three points will be noted: (1) The rate of wear diminishes with the decrease of tin, as above stated. (2) The rate of wear decreases with the increase of lead. (3) Arsenic and phosphorus apparently have no bearing on the wearing qualities. My work here again has been but of a confirmatory kind. Taking up the same thread, I began with the alloy of 5 per cent. tin, holding this constant in all following alloys examined, but increasing the lead 5 per cent. each time.

Copper 90 per cent., Tin 5 per cent., Lead 5 per cent.—Microscopically, this alloy shows the presence of pure copper, practically pure lead in mechanical admixture, and the copper-tin eutectic (consisting of copper and crystals of $SnCu_3$). I am not prepared to say if there also exists one or more complicated eutectics; this is quite probable. I have some information bearing on this point, but as a discussion of this will be quite lengthy, will omit it here.

The lead, as naturally supposed, covers but a small portion of the field.

Machine test:

Friction in pounds	16
Temperature above room, degrees F.	53
Wear, in grams	·0542

Copper 85 per cent., Tin 5 per cent., Lead 10 per cent.—This alloy shows the same general characteristics as the foregoing, but a larger field occupied by the lead. The lead is clearly seen without etching, and is shown to be held in little pockets or network of copper and tin.

Machine test:

Friction	18½
Temperature above room	56
Wear, in grams	·0308

Copper 80 per cent., Tin 5 per cent., Lead 15 per cent.—Microscopically the same as above.

Machine test:

Friction in pounds	18½
Temperature above room, degrees F.	58
Wear, in grams	·0327

In view of the foregoing knowledge it seemed to be highly desirable to produce an alloy with as much lead and as little tin as possible, not only for the reason that such an alloy is less liable to heat in service, and at the same time show a diminished rate of wear, but also because the two expensive metals, viz.: copper and tin, are replaced by a far cheaper metal—lead.

The metal known as Ex. B. composition—tin 7 per cent., lead 15 per cent., copper 78 per cent.—was adopted as the result of Dr. Dudley's work, he stating that this alloy, according to their then present knowledge, was the best that could be devised, and I take the liberty of using the following quotation from his before-mentioned paper: "Some experiments have been made towards the still further diminution of tin and increase of lead, but it is found that a certain amount of tin is necessary to hold the lead alloyed with the copper, and apparently the limit of diminution of tin and increase of lead is not a great ways from the composition of alloy B." Summing up the valuable knowledge as set forth by Dr. Dudley, appreciating fully the benefits to be derived, could a method be found of making successful castings on a large scale, with lower tin and higher lead content? We gave the matter careful attention, and carried on an elaborate series of experiments, but time will not permit me to go into details of same; but suffice it to say that the fact was discovered that a certain amount of tin was necessary for retaining the lead without segregation, and also to give the alloy requisite compressive strength, but that a greater amount is exceedingly detrimental. We were able to produce, without difficulty, alloys with 5 per cent. tin and 30 per cent. lead, but were unable to obtain castings containing 30 per cent. lead, if the tin exceeded 6 to 6½ per cent., nor could we produce castings with even slightly above 20 per cent., when 7 per cent. of tin was exceeded. This seemed very strange, as naturally one would suppose if a small amount of tin will hold a certain amount of lead, a larger amount should hold still more. The most satisfactory explanation we could find for this, and which is contained in our patent covering this alloy, is as follows: As I explained when discussing the copper-tin alloy, the same was made up of dendrites of copper, a chemically constituted alloy of copper and tin and eutectic—the eutectic being made up of laminæ of $SnCu_3$ and laminæ of copper, and being found by analysis to contain 73 parts copper and 27 parts tin, and having solidifying point of approximately 930° F., while the copper solidifies above 1,800°.

Now, as the tin is increased, the eutectic is increased, and one can readily imagine that when a large bulk of the alloy must cool down from the casting temperature above the melting-point of copper (to 930°) it must necessarily remain a long while in the liquid state in the mold. The lead, as I have shown, is but mechanically held by the network of copper and tin, and having a solidifying point more than 300° below the eutectic, has abundant opportunity, owing to its high specific gravity, to liquate to the bottom of the casting, and this, in fact, is exactly what happens; but in the absence of eutectic, or in the presence of but small amount of it, solidification takes place soon after entering the mold, and forms the copper-tin network, which envelops and upholds the still liquid lead. This is evidenced by the fact that such castings may be withdrawn from the sand when still red-hot (far above the solidifying point of lead), and yet show no sweating of the above metal.

It is quite possible, on a small scale and under certain conditions, viz.: as in pouring into chill molds, to obtain fairly uniform alloys without adhering strictly to the proportions which we have claimed in our patent covering this alloy; but the proportions as here set forth are the only ones in which satisfactory castings can be made on a large scale—our claim being a bearing containing less than 7 per cent. tin and more than 20 per cent. lead, and the balance copper, substantially as described.

The results obtained by adhering to the above proportions, however, are not entirely what may be desired for every-day practice. The presence of some detrimental impurities or casting at a too elevated temperature often causes slight segregation. The thought now came to our minds to obtain some means of more rapidly chilling the castings. The casting in iron molds being entirely impracticable for manufacture of many miscellaneous patterns, made us seek for some better means. The thought came, is it possible to add some element directly to the alloy, which will have the desired effect? After going over the whole list of high-melting-point metals, nickel was found to be the only one which answers in a practical way. It unites readily with copper, and the presence of from ½ to 1 per cent. is found sufficient to cause a rapid setting of the cast metal; this forms the basis for a second patent bearing on the same alloy—a process for preventing segregation in the copper-lead alloy, which consists in adding thereto small proportion of nickel, substantially as described.

This alloy is now known in the trade as "Plastic Bronze," and has become a thoroughly commercial article. It has been on the market hardly three years, but has been made in an amount which approximates 4,000,000 pounds. It has been cast in all manner of patterns, weighing from a fraction of a pound to over 1,000 pounds each, and is handled as readily in the foundry as phosphor-bronze, manganese bronze, or any of the more common alloys. Castings are sharp and clean. It machines readily, and, in fact, possesses all the qualifications essential for practical purposes.

Having accomplished the production of an alloy containing upwards of 20 per cent. lead, the next object was to test it in the manner of the previous ones, the tin being kept constant at 5 per cent.

Copper 75 per cent., Tin 5 per cent., Lead 20 per cent.—It will be noted that no nickel was used in the test bearings, as it was thought desirable to have no other elements present.

Microscopically the alloy showed the same structure—network of copper and tin, and large area mechanically held lead.

MACHINE TEST.

Friction in pounds	18½
Temperature above room, degrees F.	58
Wear, in grams	·0277

Copper 70 per cent., Tin 5 per cent., Lead 25 per cent.—Same as above.

MACHINE TEST.

Friction in pounds	18
Temperature above room, degrees F.	58
Wear, in grams	·0204

It will be noted the friction here is apparently little less than above.

Copper 65 per cent., Tin 5 per cent., Lead 30 per cent.—Microscopically examined, large portion of the field is shown to be covered by lead.

MACHINE TEST.

Friction in pounds	18
Temperature above room, degrees F.	64
Wear, in grams	·0130

The following table will show the above results in classified form, giving the exact formula of each alloy as determined by chemical analysis:

COPPER AND TIN, AND COPPER, TIN AND LEAD SERIES.

	Copper.	Tin.	Lead.	Friction.	Temperature above Room.	Wear, in Grams.
1	85·76	14·90	. . .	13	50	·2800
2	90·67	9·45	. . .	13	51	·1768
3	95·01	4·95	. . .	16	52	·0776
4	90·82	4·62	4·82	14	53	·0542
5	85·12	4·64	10·64	18½	56	·0380
6	81·27	5·17	14·14	18½	58	·0327
7	75?	5?	20?	18½	58	·0277
8	68·71	5·24	26·67	18	58	·0204
9	64·34	4·70	31·22	18	44	·0130

The conditions in all above-described tests were as follows:

Total number of revolutions made	100,000
Revolutions per minute	525
Size of journal, 3¾″ diameter, 3½″ long.	
Pressure per square inch in pounds	1,000
Lubrication—Galena coach oil, fed by cotton waste.	

Tests were made with higher-lead-content alloys, and also copper, lead and nickel alloys without tin, but time will not permit me to discuss these.

The alloy which we have adopted consistent with proper strength for general purposes and with the best foundry results is copper 64 per cent., tin 5 per cent., lead 30 per cent., and nickel 1 per cent.

It will be noted that what is true of the alloys of 15 per cent. lead and under, as examined by Dr. Dudley, is also true of the high-lead-content alloys, viz.: that the rate of wear diminishes with increase of lead, or, in other words, the rate of wear diminishes with the diminishing compressive strength or increased plasticity of the alloy. This alloy has plasticity resembling babbitt metals, and for this reason can fairly be expected to show a less tendency to become heated. This has been amply proven in actual service.

There remains several other classes of bronzes, which, owing to their low cost of production, are largely used. They are alloys of copper and tin containing zinc, or containing both zinc and lead. Such alloys as these can be made from miscellaneous junk, and hence the low cost of production.

Foundry and machine tests have been made of a number of these, which brought out the following conclusions:

(1) Zinc increases the rate of wear.

(2) Zinc has a tendency to segregate lead.

The following table will be of interest in this connection. Effort was made to keep the tin and lead as constant as possible, and replace copper by zinc.

	Copper.	Tin.	Lead.	Zinc.	Friction.	Temp. ab. room.	Wear, in grams.
5	85·12	4·64	10·64	. .	18½	56	·0280
10	82·27	5·28	10·25	2·07	18½	68	·0415
11	79·84	4·71	10·30	5·44	18½	66	·0466
12	77·38	5·62	11·42	6·54	18½	68	·0472
13	74·28	4·68	10·61	11·04	18½	69	·0846

CONDITIONS—SAME IN ALL TESTS.

Total number of revolutions	100,000
Revolutions per minute	525
Journal 3¾ inches diameter, 3½ inches long	
Pressure per square inch in pounds	1,000
Lubrication—Galena coach oil, fed by cotton waste.	

These miscellaneous alloys, containing copper, tin, lead, zinc, iron and other metals, form a very large part of the present railway equipment in bearings, it having long been the practice to use junk of every conceivable variety in their manufacture. Materials which could not be used for any other purpose were considered good enough for car brasses; but railroad officials are gradually becoming educated to the fact that the best is none too good.

We have recently put in operation a patented process for the refining of copper-tin-lead alloys containing detrimental impurities, such as zinc, iron and other electro-positive metals. A description of this process will probably make the substance of a future paper.

In conclusion I wish to express my gratitude to Dr. Dudley for his valuable work preceding our own, for the test which he has conducted in service of our plastic bronze bearings, and the many valuable hints which he has given me from time to time.

I also wish to acknowledge my gratitude to Charpy and Stead for their valuable work in the study of the constitution of alloys.

ALLOYS OF LEAD, TIN AND ANTIMONY.

Lead.	Tin.	Antimony.	References.
94	—	6	Alloy analyzed by Dudley.
88	—	12	Alloy analyzed by Dudley.
85	—	15	Quoted by Hiorns (soft alloy). Quoted also by Dudley.
84	—	16	" " Ledebur. For slow-revolving pulleys.
80	12	8	Used by Eastern Railroad (France) for metallic packings.
77·7	5·9	16·8	Quoted by Thurston, as being the composition of Magnolia and Tandem metals.
76	14	10	Used for metallic packings by the Orleans and P. L. M. Railroads.
73	12	15	Metallic packings of piston rods. Northern Company (France).
70	20	10	Metallic packings of eccentric collars. French state railroads.
68	15	17	Graphite (?) metal analyzed by Dudley.
60	20	20	Quoted by Ledebur. Railroad bearings.
42	46	12	" " Hiorns Hoyles metal.
42	42	16	" " Ledebur. Journal boxes. French state railroads.
40	45	15	" " Ledebur.
37	38	25	" " Thurston Italian railroad companies.

ALLOYS OF TIN, COPPER AND ANTIMONY.

Tin.	Copper.	Antimony.	References.
96	4	8	Quoted by Thurston. Ordinary bearings.
90	2	8	" " " Quoted by Hiorns for bearings heavily loaded; used by Russian railroads for car bearings
88·8	3·7	7·4	Quoted by Thurston and Bolley, as Karmarsch metal. Used in France in naval constructions.
87·5	12·5	—	" " Thurston. Karmarsch metal.
87	6	7	" " Hiorns, for bearings heavily loaded.
85	5	10	" " Ledebur and Hiorns as Jacoby metal for light pressure.
83·33	5·55	11·11	Used for car bearings, "Compagnies de l'Est, P. L. M., Ouest," etc.
83	6	11	Quoted by Ledebur. Used by Berlin railroads.

Tin.	Copper.	Antimony.	References.
82	6	12	Quoted by Ledebur. Used by Orleans and the Western Austrian railroads.
82	8	10	Bearings for valve rods and eccentric collars, "Compagnie du Nord."
81·25	6·25	12·5	Quoted by Thurston and Bolley.
81	5	14	" " Hiorns, for very hard bearings.
80	10	10	" " Thurston. Used by Swiss railroads.
79	—	21	" " Hiorns.
78·5	10	11·5	" " Thurston. Used by Russian railroads.
76·7	7·8	15·5	" " Ledebur and Thurston as English alloy.
76	7	17	" " Hiorns, for bearings lightly loaded.
75	—	25	" " Thurston and Bolley, as Karmarsch metal
73	9	18	" " Thurston and Hiorns, for light pressure.
72·8	9	18·2	" " Ledebur.
72	2	26	" " Thurston and Bolley.
71·4	21·4	7·2	" " Thurston. Karmarsch metal.
71	5	24	Thurston standard white metal. Used by the P. L. M. Company for packing of valves and eccentric collars.
70 73	9·75	19·5	Quoted by Thurston.
67	22	11	" " Thurston. Used by the Great Western Railway (England).
67	11	22	French state railroads.
33·3	22·2	44·5	Quoted by Hiorns. Dewrance metal for locomotives.
12	4	82	" " " for very hard bearings.

ALLOYS OF COPPER, TIN AND ZINC.

Copper.	Tin.	Zinc.	References.
97·2	—	2·5	Quoted by Bolley.
89	8	3	" " Thurston for locomotive bearings.
89	9	2	" " " Italian railroads.
87	8	5	" " Bolley. Hard alloy.
86	14	—	" " Thurston for locomotive bearings.
86	12	2	" " Ledebur. Bearing alloy.
85·25	12·75	2	" " Thurston.
84	14	2	Used by French State railroads for pieces subjected to alternative friction.
83	15	3	Lafond alloy for heavily loaded bearings.
82	18	—	Quoted by Ledebur and Thurston. Car bearings of the "Compagnie du Nord."
82	10	8	Quoted by Bolley.
82	15	3	Orleans Railroad. Valve-rod bearings.
82	16	2	Quoted by Ledebur for locomotive bearings. Used by French State railroads for pieces subjected to circular friction.
80	18	2	Quoted by Thurston and Bolley. Lafond alloy.
78·7	6·3	15	" " Bolley for friction upon cast iron.
78	20	2	" " " and Thurston for car bearings.

Copper.	Tin.	Zinc.	References.
77·4	15·6	7	Quoted by Haswell. Hard bronze for bearings.
58	28	14	" " Thurston. Margraff alloy.
57	14	29	" " Hiorns for propelling-screw shafts.
56	28	16	" " Thurston. Fenton alloy.
6	14	80	Quoted by Hiorns and Thurston. Fenton alloy for locomotive and car bearings.
5·5	17·5	77	Quoted by Ledebur, for high-speed horizontal shafts.
1·6	98·23	—	Antifriction metal analyzed by Dudley.

MISCELLANEOUS ALLOYS.

Copper.	Tin.	Lead	Zinc.	Iron.	Antimony.	Phosphorus.	References.
10	—	65	—	—	25	—	Bearings for locomotives and tenders.
74	9·5	7	9·5	—	—	—	Quoted by Thurston and Ledebur. Locomotive bearings.
79	8	8	5	—	—	—	Quoted by Bolley and Ledebur. Bearings for engines.
5	—	—	85	—	10	—	Quoted by Ledebur.
8·3	7·6	3	83·3	—	3·8	—	Quoted by Ledebur as Pierrot metal, Beugnot white bronze, used in France in naval constructions.
5·6	17·5	0·7	76·2	—	—	—	White bronze used for ship engines.
1·6	46	—	52	—	0·4	—	Dunnlevic and Jones metal.
4	19	5	60	—	3	—	Quoted by Ledebur. Babbitt metal.
—	15	25	50	—	—	—	Quoted by Ledebur. Kniess metal.
5	32	60	—	—	3	—	Used by the western railroads (France) for piston-rods and eccentric packings.
4	73	7	—	—	12	Phosph. Copper. 4	Packing for bearings and eccentric collars. Western Railroad (France).
70·20	4·25	14·74	10·20	0·55	—	—	Camelia metal analyzed by Dudley.
4·01	9·91	1·15	85·57	—	—	—	Salge antifriction metal analyzed by Dudley.
75·47	9·72	14·57	—	—	—	—	Carbon bronze analyzed by Dudley.
77·83	9·60	12·40	—	—	—	—	Cornousilles bronze analyzed by Dudley.
92·39	2·37	5·10	—	0·10	—	—	Delta metal analyzed by Dudley.
—	—	83·55	—	—	16·45	—	Magnolia metal analyzed by Dudley.

Copper.	Tin.	Lead.	Zinc.	Iron.	Antimony.	Phosph. Copper.	References.
—	—	78·44	0·98	0·65	19·60	—	American antifriction bronze analyzed by Dudley.
59	2·16	0·31	38·40	0·11	—	—	Tobin bronze analyzed by Dudley.
78·50	9·20	15·06	—	—	—	—	Graney bronze analyzed by Dudley.
76·41	10·60	12·52	—	—	—	—	Damar bronze analyzed by Dudley.
90·52	9·58	—	—	—	—	—	Manganese bronze analyzed by Dudley.
81·24	10·98	7·27	—	—	—	0·37	Ajax bronze analyzed by Dudley.
						Phosphorus.	
55·73	0·97	—	42·67	0·68	—	—	Harrington bronze analyzed by Dudley.
—	—	84·33	—	0·61	14·38	—	Bearing metal for cars analyzed by Dudley.
79·17	10·22	9·61	—	—	—	0·94	Phosphor-bronze analyzed by Dudley.
76·80	8	15	—	—	—	0·20	B. metal. Car bearings of the Pennsylvania Railroad.

Composition of the Alloy.	Loss of Weight per sq. cm. after Twenty Minutes.
Pure lead	0·008
20 per cent. antimony	0·180
30 " " "	0·328
40 " " "	0·404
50 " " "	0·588
60 " " "	0·700
Pure antimony	1·160

DISCUSSION.

Mr. Paul Kreuzpointner asked whether any experiments had ever been made to determine the amount or ratio of wear of bearing metal of a fine-grained structure and a coarse-grained structure; or, in other words, whether a fine-grained structure offered any decided practical and economic advantages.

Mr. Clamer:—I have no absolute figures to show the rate of wear of a fine-grained alloy as compared with a coarse-grained alloy of the same composition. But in a general way I think it is quite well known that a fine-grained alloy will show a slower rate of wear. Our idea or definition of wear is "the tearing off of small particles from the worn body," and Dr. Dudley, in a paper read before this Institute some years ago, showed that in consequence of this conception of wear, it must necessarily follow that a metal of fine-grained structure will wear slower, owing to the smaller size of the torn-off grains. His observations were particularly in connection with rails, but undoubtedly the same holds good for bearings.

MR. A. E. OUTERBRIDGE, JR., asked if the author had ever had any experience with the casting of metal in chill molds, and if so, what effect he had noted on the quality of the metals. He also referred to some observations he had made while connected with the Philadelphia Mint regarding the structure of a copper, tin and zinc alloy, used for manufacture of pennies, when cast in sand, and the same metal when cast in a chill.

MR. CLAMER :—Some years ago I had some experience in this connection in casting car bearings, and so far as the structure and physical properties were concerned, viz.: tensile strength and elongation, the chill castings showed a decided improvement, but the difficulty experienced was in obtaining castings free from blow-holes, and to obtain a satisfactory mold which could be easily handled, and the great expense attached to getting up such molds for miscellaneous castings, owing to the great number required.

MR. ROBERT JOB :—I have been very much interested in Mr. Clamer's study of bearing metals, and am glad to note the systematic manner in which his composition has been worked out. Everyone concerned in motive power and equipment matters is directly interested in the problem of reduction of hot boxes, and careful attention has been given the subject upon many roads. The composition of the bearing is an important matter, but it is but one of a number of variables, each of which may greatly affect the final outcome in service. Correct foundry practice is a most essential factor, as also are the fitting of the bearing, the lubrication and the quality of packing-waste, as well as the efficiency of the protection of the bearing from dust and cinders. A special study of these matters was begun upon the Reading Railway several years ago, and some account of the general results appeared in the *Journal* of this Institute in June, 1900. By following out these and other lines of work I am glad to say that a very marked reduction in the number of hot boxes has been effected in the past few years, in spite of material additions to our car and locomotive equipment.

Hot boxes are not by any means the necessary attendant of train service that they sometimes are considered, and careful study of the conditions and causes in any particular case may often effect remarkable changes.

Book Notices.

Galvanic Batteries: Their theory, construction and use; comprising primary, single- and double-fluid cells, secondary and gas batteries. By S. R. Bottone. (With 144 illustrations.) 8vo, pp. xvi + 376. London and New York: Whittaker & Co. 1902.

So far as the reviewer is aware, there is no modern work in English treating of this important branch of applied electricity. The works of Napier, Niaudet and Prescott, very useful in their day, are now more or less antiquated, and a modernized work on the subject by an author of good repute should prove a welcome addition to current electrical literature. W.

The A B C of Photomicrography: A practical handbook for beginners. By W. H. Walmsley, F.R.M.S., etc. 12mo, pp. viii + 155. New York: Tennant & Wood. 1902.

The author endeavors in this work to fill the need for a handbook of instruction in the elementary branches of the art of photomicrography, concerning which there appears to be a dearth of literature. Mr. Walmsley is one of the pioneers in this field and an expert of the highest repute. His book should fill its intended purpose thoroughly well. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, June 17, 1903.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 17, 1903

President JOHN BIRKINBINE in the chair.

Present, 56 members and visitors

Additions to membership since last report, 17.

The election of a member of the Board of Managers to take the place of Mr. James M. Dodge, lately elected Vice-President, was, on motion, postponed until the next stated meeting.

Prof. Lewis M. Haupt read a paper "On the Control of the Floods of the Mississippi River," and by special request supplemented this by a communication "On the Conservation and Increase of the Beach Front at Atlantic City, N. J." Both communications were illustrated with the aid of lantern slides.

The thanks of the meeting were voted to the speaker, and his communications were referred to the Committee on Publications.

The Yawman & Erbe Manufacturing Company, of Philadelphia, through one of its representatives, described and made a demonstration of a Rapid Roller Copying Machine for copying letters. Referred to the Committee on Science and the Arts.

Mr. W. N. Jennings exhibited a number of interesting lantern photographs, including a view over Boston, made from a free balloon by Prof. Samuel A. King, in October, 1860, and one of the alto-reliefs in the Broad Street Station of the Pennsylvania Railroad, made by an exposure of one hour to the incandescent electric light illuminating the Station.

Adjourned.

LOUIS E. LEVY,
Secretary pro tem.

Committee on Science and the Arts.

[*Abstract of proceedings of the stated meetings held May 6 and June 3, 1903.*]

MR. CHAS. E. RONALDSON in the chair.

The following reports were adopted:

(No. 2181.) *Enclosed Arc Lamp.*—C. J. Toerring, Philadelphia. Previously reported. On reconsideration, the Edward Longstreth Medal of Merit is awarded to the inventor. [*Sub-Committee.*—L. F. Rondinella Chairman; T. C. Smith, A. J. Rowland, W. C. L. Eglin, C. C. Heyl, Wm. McDevitt.]

(No. 2230.) *Speed Controller.*—Consolidated Machine Specialty Company, Boston, Mass..

Not susceptible of abstraction without illustrations. The Edward Longstreth Medal of Merit is awarded to the Company. [*Sub-Committee.*—Chas. Day, Chairman; Tinius Olsen, Lucien E. Picolet.]

(No. 2272.) "*Radial-Duplex*" *Gang Cutters.*—Gould & Eberhardt, Newark, N. J. (An advisory report.)

(No. 2273.) *Enclosed Arc Lamp.*—Louis B. Marks, New York. (An advisory report.)

(No. 2274.) *Valve Mechanism.*—E. J. Armstrong, Erie, Pa. (An advisory report.)

(No 2276.) *Improvement in the Art of Butter-Making.*—Chas. M. Taylor, Jr., Philadelphia.

This invention describes an absorptive process for separating the butter-fat from the casein and watery constituents of cream. The report is reserved for publication in full. The award of the John Scott Legacy Premium and Medal is recommended to the inventor. [*Sub-Committee.*—S. P. Sadtler, Chairman; F. A. Genth, Edward Woolman, George Malony.]

(No. 2278.) *Speed-Changing Pulley.*—Speed-Changing Pulley Company, Indianapolis, Ind. (An advisory report.)

(No. 2286.) *Improvements in Steam Engines.*—Peter Christian, Johnstown, Pa. (An advisory report.)

The following reports passed first reading:

(No. 2240.) *Heat Gage.*—E. F. Morse, Trumansburg, N. Y.

(No. 2252.) *Enclosed Fuse Protective Devices.*—Joseph Sachs, Hartford, Conn.

(No. 2261.) *Process of Fireproofing Wood.*—Joseph L. Ferrell, Philadelphia.

(No. 2263.) *The Addressograph.*—Addressograph Company, Chicago. Ill.

(No. 2271.) *Brazing Cast-Iron.*—American Brazing Company, Philadelphia.

(No. 2287.) *Spiral Elevator.*—D. E. Condon, San Francisco, Cal.

(No. 2293.) *The School City.*—Wilson L. Gill, New Paltz, N. Y.

W.

[*Abstract of proceedings of the adjourned meeting of June 10th and of the special meeting of June 16th.*]

June 3d, MR. CHAS. E. RONALDSON in the chair.

The following reports were adopted:

(No. 2240.) *Heat Gage.*—Everett F. Morse, Trumansburg, N. Y.

ABSTRACT.—This invention is protected by several letters-patent of the United States, Nos. 696,619 and 695,828, issued to applicant April 1, 1902. The first covers the process, and the second the method of gaging the temperature by heated substances.

The report is reserved for publication in full. The John Scott Legacy Premium and Medal is recommended to the inventor. [*Sub-Committee.*—G. H. Clamer, Chairman; John M. Hartman.]

(No. 2252.) *Enclosed Electric Fuses.*—Joseph Sachs, Hartford, Conn.

ABSTRACT.—The fundamental patent covering this invention is numbered 522,252, and dated July 3, 1894. A number of patents have been issued covering details.

The report finds that applicant has greatly improved the art by the introduction of a solvent flux in the interior of the chamber and surrounding the fuse. The function of this flux is to dissolve and remove from the surface of the fuse the coating of oxide which is formed, and which tends to retain the metal of the fuse-wire in the circuit after it is melted, thus preventing an immediate rupture of the circuit.

The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—C. J. Reed, Chairman; Thomas Spencer, Francis Head.]

(No. 2261.) *Process and Apparatus for Fireproofing Wood.*—Joseph L. Ferrell, Philadelphia.

This report is reserved for publication in full. The Elliott Cresson Medal is awarded to the inventor. [*Sub-Committee.*—Richard L. Humphrey, Samuel P. Sadtler, Wm. McDevitt, A. Raymond Raff.]

(No. 2263.) *The Addressograph.*—The Addressograph Co., Chicago, Ill.

ABSTRACT.—This invention is intended to solve the problem of rapidly addressing, for mailing purposes, circulars, wrappers, etc., for periodical publications, and is a labor-saving device of the highest importance. It is protected by letters-patent of the United States, as follows: No. 558,936, April 28, 1896; No. 579,706, March 30, 1897; and No. 656,442, August 21, 1900, granted to J. S. Duncan, Chicago, Ill.

The report is not adapted for intelligible abstraction without the aid of illustrations. The John Scott Legacy Award is recommended to the inventor. [*Sub-Committee.*—J. Logan Fitts, Chairman; Ernest M. White.]

(No 2271.) *Brazing Cast-Iron.*—American Brazing Co., Philadelphia.

ABSTRACT.—This process is the invention of Frederick Pich, and is protected by letters-patent of the United States, No. 647,631, of April 17, 1900, and No. 688,030, of December 3, 1901.

The first patent describes a method for brazing or hard-soldering of cast-iron, and the latter a soldering compound or flux for said purpose.

The flux is a mixture of sub-oxide of copper or of other oxides with borax. By the use of this material soldering of cast-iron is readily accomplished at a temperature sufficiently high to melt the solder. A Certificate of Merit is awarded to the Company. [*Sub-Committee.*—G. H. Clamer, Chairman; J. M. Hartman, Thos. P. Conard, Frank Roselle.]

(No. 2286.) *Improvements in Steam Engines.*—Peter Christian, Johnstown, Pa.

(An advisory report.)

(No. 2287.) *Spiral Elevator.*—Daniel E Condon, San Francisco, Cal.

(An advisory report.)

(No 2293.) *The Educational System called "The School City."*—Wilson L. Gill, New Paltz, N. Y.

Reserved for publication in full. The Elliott Cresson Medal is awarded to the inventor. [*Sub-Committee.*—Louis E. Levy, S. P. Sadtler, H. F. Keller] W.

Sections.

[*Abstracts of stated meetings.*]

ELECTRICAL SECTION.—*Stated meeting* held Thursday, May 28th, 8 P.M. Mr. Thomas Spencer in the chair Present, 30 members and visitors.

The meeting was devoted to the reading and discussion of a paper by Mr. Percy H. Thomas, Westinghouse Electric and Manufacturing Company, Pittsburg, on "Static Discharges on Electric Circuits." The paper was fully illustrated with the aid of apparatus and diagrams, and will be published in full in the JOURNAL.

The meeting passed a vote of thanks to the speaker and adjourned.

WM. H. WAHL,
Secretary pro tem.

JOURNAL

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

Mining and Metallurgical Section.

Stated Meeting, held Thursday, May 14, 1903.

The Utilization of Blast-Furnace Gases for Power Purposes.

BY CHARLES KIRCHHOFF,
Honorary Member of the Institute.

A splendid example of the co-operation of different branches of engineering is furnished by the recent development in the utilization of waste blast-furnace gas for power purposes. The metallurgist has adapted himself to the requirements of the mechanical engineer, while the latter has worked out the problem of using a gas of low thermal value in large units of internal combustion engines, the electrical engineer stepping in through the concentration of power development by electrical transmission to isolated installations.

The fact that the blast furnace is nothing more than a huge gas producer was realized long ago, and it was one of the long steps in the direction of a more complete utilization of the fuel charged into the furnace when the system of heating the blast and of producing steam for the blowing engines was introduced. But for generations progress was confined to improvements in the design and construction of hot-blast stoves and of boilers and blowing engines, although some metallurgists, notably Luermann, urged that there was much room for further economies, since the calorific capacity of waste blast-furnace gas was far from being effectively utilized. How inadequate the prevailing methods were is proven by the fact that a good deal of coal was burnt at blast-furnace plants in order to cover their own requirements.

In the meantime the gas engine, first employed exclusively in small units and with illuminating gas, invaded new fields, and successfully grew in size. Builders learned to use producer gas and built larger and larger units, until finally Delamare Deboutteville brought out the Simplex gas engine, which was adopted by the Société Cockerill at Seraing, Belgium, whose engineers had begun the study of the subject in 1895. A year earlier, however, B. H. Thwaite, an Englishman, had urged the use of blast-furnace gas for driving gas engines, and he must probably be regarded as the pioneer in this field. The Simplex engine had been running on poor producer gas, and experiments first began at Seraing, with a 4-horse-power engine of that type, changed later to an 8-horse-power engine. Later still M. Delamare Deboutteville was instructed to design a 150-horse-power engine, which was started in the spring of 1898. Then came the famous Cockerill engine of 600 horse-power at the Paris Exposition, which focussed the attention of iron-masters upon the subject. In the meantime experiments had been carried on at Hoerde, in Westphalia, and the Germans took hold of the problems involved very vigorously.

In our own country development has been along somewhat different lines. The utilization of waste furnace gas had been neglected, and even now many of our leading furnacemen maintain an attitude of reserve. The only exception is Mr. Henry Wehrum, chief engineer of the Lackawanna

Steel Company, who is putting in three plants, one of eight 1,000-horse-power engines to drive dynamos and two others of together sixteen 2,000-horse-power engines, which are to drive blowing engines, the whole installation to be a part of the great new steel plant at Buffalo.

In this country, the large unit gas engine has been developed by Westinghouse, and particularly by E. C. Luffkin, of the Snow Steam Pump Works, who has used them exclusively for pumping natural gas and being operated by the same. The Standard Oil Company has, during the past few years, gone extensively into the collection and distribution of natural gas and has, for instance, laid down lines from West Virginia to Cleveland and a number of Ohio interior towns. It is understood that there are now practically completed two gas engines of 4,000-horse-power, which are being installed for this service at Cleveland.

One of the reasons why American engineers have been so slow to use furnace gas is that, particularly in all the districts in which Lake Superior ores are used, the gases are laden with the dust from the fine Mesaba ores.

How rapidly the use of blast-furnace gas engines has spread is shown by a compilation made in the fall of 1902 by Herbert A. Humphrey, who has a list of engines in Europe and the United States of over 200-horse-power. He enumerates 327 engines capable of supplying 181,605 horse-power. This does not include many more recent installations, so that to-day there are probably built or building 225,000 horse-power of large gas engines, of which by far the greater number operate with blast-furnace gas.

There is every reason to believe that this is really only the beginning of a movement which will culminate in supplying a very large amount of power, to be used either to operate the machinery of adjacent steel works, rolling mills or factories, or to be employed in making calcium carbide or other electrometallurgical products. Some conception of the magnitude of this hitherto wasted energy may be gathered from the following figures: Assuming, as we have a right to do, that 25 per cent. of the heat energy of the gas can be realized in effective power, there is available, after deducting the requirements of the furnace plant, at least 800 horse-power for every ton of iron produced per hour.

At the present output in the United States, of 19,500,000 tons per annum, we are making 2,250 tons per hour, or have an available surplus of 1,800,000 horse-power. At as low a rate as $15 per horse-power per annum, this country, if its blast furnaces were equipped with gas engines, would save $28,800,000. Or, putting it in another way, a modern furnace producing 500 tons of iron per day would, at $15 per horse-power, save $250,000 per annum, which on its cost of about $1,000,000 would pay for very liberal depreciation and renewals and leave a handsome dividend. Of course, only the first-comers could hope to secure such revenues, since when the use of gas engines became general, competition would soon lead to a corresponding reduction in prices. In many cases the character of the coal being coked would place at the disposal of the furnace manager an additional surplus of power. At one great plant in this country preliminary computation showed that in coking the coal at the works in by-product ovens the steam required for the rolling mills might be covered from its waste gases, and that then nearly 49,000 horse-power would be for sale, which, at $16 per horse-power, would realize $775,000 per annum. The utilization of the waste gases is therefore a matter of the keenest interest to the iron maker, and holds out the promise of brilliant rewards.

It would take us altogether too far to follow in detail the computations by which closely accurate data relative to the quantity and quality of the waste furnace gas can be arrived at. Mr. E. A. Uehling has presented figures in an interesting paper published in the *Stevens Indicator*. But some of the principal data may be presented which summarize the results of an investigation made by Mr. Henry Wehrum, of the Lackawanna Steel Company, who took as the basis Lake ores of well-determined composition. The total charge per ton of iron consists of 1·56 tons of ore, 0·33 ton of flux, 0·85 ton of fuel and 3·55 tons of blast, a total of 6·31 tons. The products are 1 ton of pig iron carrying 3·5 per cent. of carbon, 1·0 per cent. of silicon, and 0·06 of phosphorus.

The slag amounts to 0·37 ton carrying 33 per cent. of silica, while the total weight of the gas per ton of pig iron would amount to 4·942 tons. In other words, for each ton of pig iron produced there escapes from the furnace nearly five times the weight of gas. This would carry, by volume, 23·77 per cent. of carbonic oxide, 14·74 per cent. of carbonic acid, 59·45 per cent. of nitrogen, 1·72 per cent. of hydrogen, 0·03 per cent. of water, and 0·27 per cent. of methane. There is available from this gas, by combustion with 20 per cent. excess of air per ton of pig iron made, 11,200,000 British thermal units, or 4,800 horse-power. Mr. Uehling figures that it requires 1,932,067 thermal units, or 750 horse-power, to heat the blast per ton of pig iron to 1,200°, which, with 5 per cent. allowance for leakage, would require 1,884 pounds of gas. This leaves about 4,000 horse-power in surplus gas, or, assuming an efficiency of 25 per cent. for the gas engines, about 1,000 horse-power. From this must be deducted about 200 horse-power to operate blowing engines, pumps, the apparatus for handling materials, lighting, etc., and there is left for sale or for other useful work 800 horse-power for every ton of iron produced per hour.

As already stated, in the old method of burning the gas under boilers and driving the machinery with steam, it took all the gas and sometimes even additional fuel to do the work. The substitution of internal combustion engines for the roundabout method through a boiler and steam-engine plant made available the large surplus referred to, which we may even hope to increase as the efficiency of the gas engines improves. Calculations are now on the basis of 25 per cent. efficiency. Actual tests show a record of 38 per cent. in the case of a Koerting double acting two-cycle engine.

A natural use to which this surplus power is put in many iron works is to drive a part of the steel works and rolling-mill machinery, the blast furnace being often an integral part of the plant. It is here that progress in another direction co-operates effectively. During the past ten years the isolated units of power plant scattered formerly over steel works and rolling mills have been concentrated in electric central stations, with a very great resultant saving of the losses in transmission. One of the first uses to which furnace-gas engines has been put is that of driving dynamos, the original obstacles to producing the alternating current in parallel having been overcome. In 1900 I had occasion to visit the Differdingen plant in Lorraine, when the installation of a plant of nine 600-horse-power furnace-gas engines was being completed. Mr. Max Meyer, the general manager, then informed me that the engines driving dynamos direct would supply power enough to operate all the machinery in the steel plant and rolling mill with the exception of the Bessemer blowing engine and those for driving the blooming mill and the large beam mill.

Some of the optimists among our engineers claim that the time will come when no steam whatever will be raised in a plant producing rolled shapes from the ore and coal up, particularly if the latter is of such a character that there is a surplus of gas from the coking operation. Of course, this means that for some of the heavy trains, like the blooming mills, enormous internal combustion engines must be provided. That, however, does not seem to frighten the enthusiasts, and I have been told that mechanical engineers are even now designing blast-furnace gas engines to develop 5,000 horse-power. One of the difficulties which suggests itself is that of coupling gas engines with roll trains, subject to such wide and sudden fluctuations in power requirements. So far as the lighter roll trains are concerned, experience in Germany has already justified the expectations of those who are blazing a new path in this branch of iron manufacture.

From a metallurgical point of view, the one difficulty which soon presented itself was the question of ridding the furnace gas not alone of the coarser dust, a part of which is caught in the dust-catcher, but also of the fine fumes which coat and corrode the engine ports and cylinders. At first the experience at Seraing seemed to indicate that this would not involve serious inconvenience, but as the gas engines found a place in other plants, it was realized that the importance of thoroughly cleaning the gas is great.

Incidentally it has become clear that it will pay to wash the gas which is used to heat the blast, because dust is kept out of the hot-blast stoves, whose efficiency is thus greatly enhanced, and whose life is thus considerably extended. A gas-cleaning plant has thus become a part of every installation.

Two methods have been pursued to get rid of the dust. One is to utilize the effect of a change in the velocity of the air current by alternate constriction and enlargement of the pipes, often combined with a moistening of the dust. This is termed the static method. The other, called the dynamic method, is to drive the gas through sprays of water. Conspicuous among these is the Theisen centrifugal purifier, in which the gases are driven around a rapidly-revolving cylinder, equipped with vanes. The interior surface of the casing is covered with wire gauze. Filtration through columns of coke or of sawdust has been employed, as at Oberhausen. Fans with water-spray have been adopted in different ways, as at Differdingen, Dudelingen, by Lencauchez at Micheville, and by Capell at Ormsby. Le Tombe at Marseilles has introduced an intermediary between the Theisen system and the fan, and at Eschweiler a static electrical system has been tried, depending on the cohering effect on suspended dust particles of static electricity. It is claimed that it has produced excellent results. Generally speaking, managers have been adequately successful in getting rid, not only of the heavier dust, but also of the light fumes, which it was more troublesome to deal with. In Europe the dust evil is now quite generally regarded as overcome, but it must not be forgotten that the trouble is not as serious as it is likely to be with us.

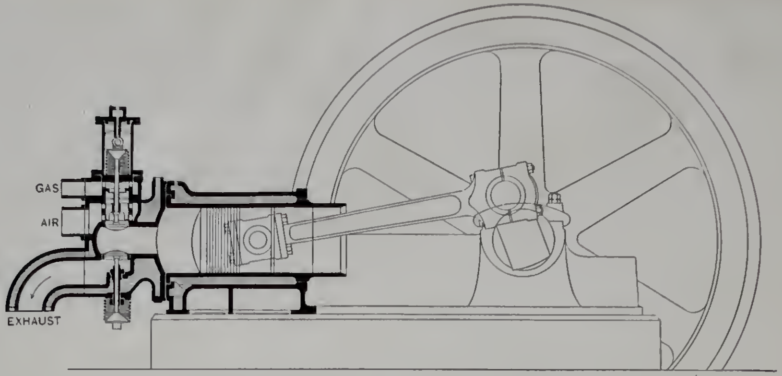
Now as to the gas engines themselves. The earlier types were the Simplex, designed by Delamare-Deboutteville, which has been modified by the engineers of the Cockerill Company and the Koerting, first put in at Hoerde. This engine is now being built in the United States by the De la Vergne Refrigerating Machine Company, of New York, while the Allis-Chalmers Company have quite recently become the licensers of the Augsburg and Nürenberg Company. According to the testimony of German engineers this more recent design has been doing exceptionally effective work.

There has been a very eager struggle for improvement in the design of large unit internal combustion engines during the past few years, and some of the most famous of the great steam-engine builders are engaged in it, since the field is very large. As a matter of fact, the utilization of waste furnace gas is only a part, and possibly only a small part, of it. It has been thoroughly proven that important economies can be effected by gasifying coal and using internal combustion engines over the old method of burning the same fuel under boilers and using steam engines. The ordinary gas producer, the Mond process, with recovery of ammonia, and the Pettibone-Loomis process, are being rapidly introduced, so that the gas engine is forging ahead for central station work, for pumping plants and miscellaneous power installations.

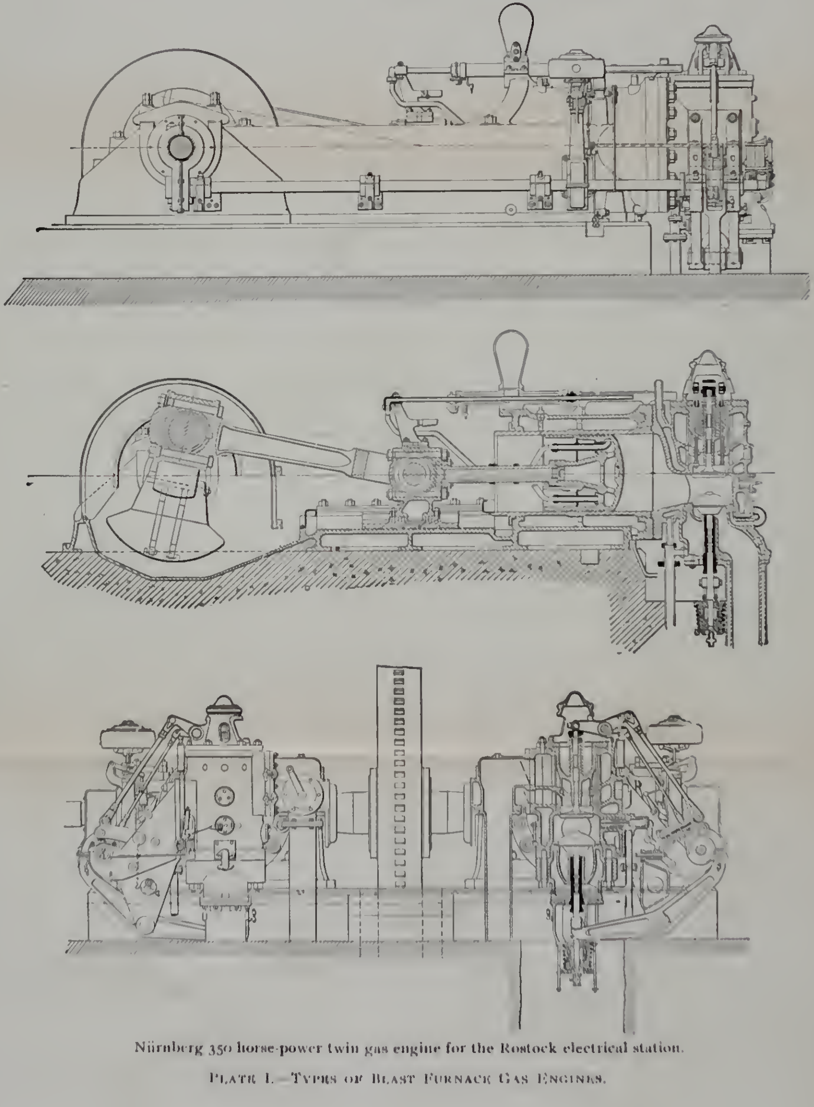
The function of the gas engine is to convert into power the impulse of an explosion of a mixture of fuel gas and air. With the poorer gases it is necessary to compress them first before satisfactory ignition and combustion can be effected. We have then the drawing or forcing into the engine cylinder of a mixture of gas and air, its compression to the required point, the ignition of the gas, and after the completion of the stroke, the expulsion of the gases of combustion. So far as the machine itself is concerned, certain considerations must guide in its design. As the result of the explosion there is a marked rise in the temperature, which might prove dangerous to the life of the engine. Elaborate cooling is therefore necessary, and the parts must be so designed that they do not suffer from temporary exposure to hot gases.

Permit me to present some of the principal engine designs, beginning first with the ordinary four-cycle or Otto-cycle engines, of which the Deutz engine is a good example. (Plate I.)

The latest Deutz design of governing gear is indicated.

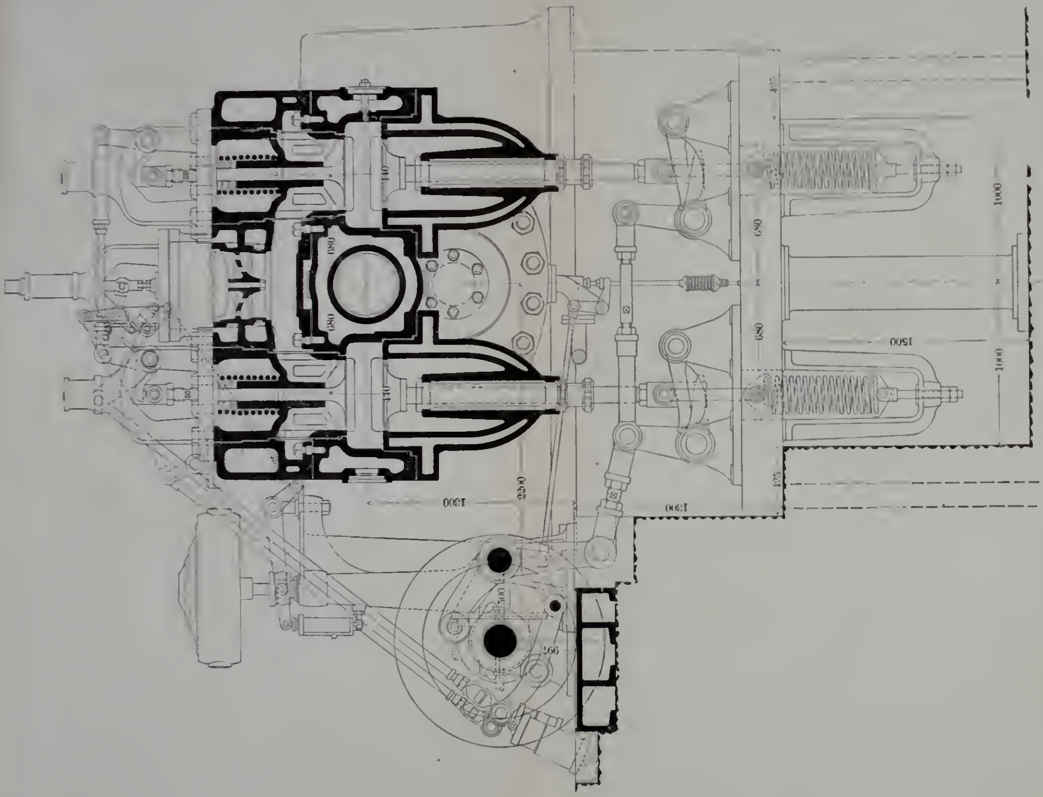


Single-acting Deutz 4-cycle gas engine. Longitudinal section.

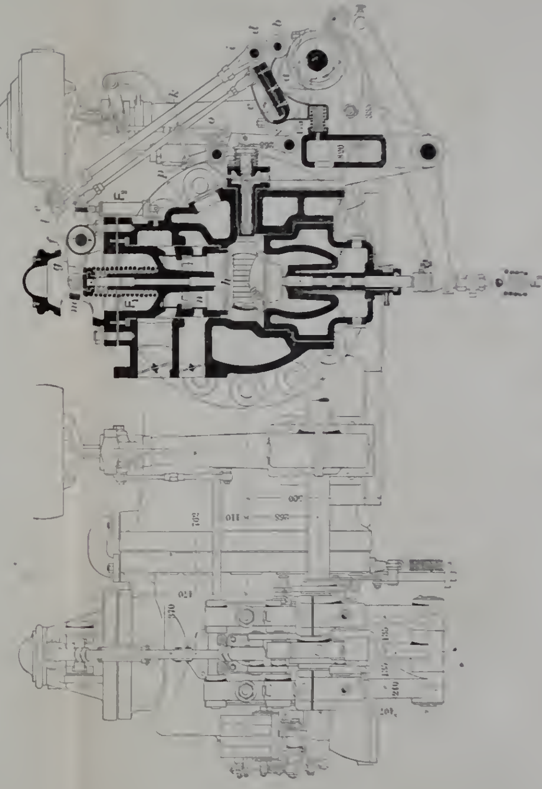


Nürnberg 350 horse-power twin gas engine for the Rostock electrical station.

PLATE I.—TYPES OF BLAST FURNACE GAS ENGINES.

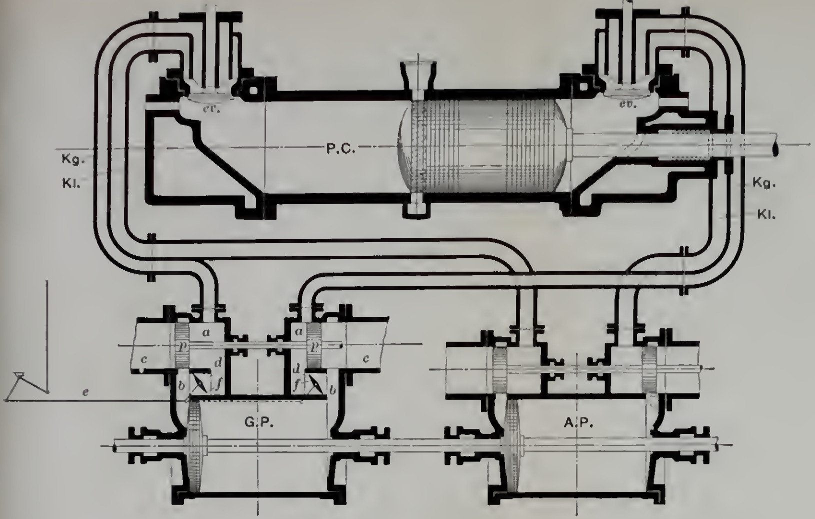


Valve-gear of 750 horse-power single-cylinder Nürnberg gas engine for Rheinische Stahlwerke.

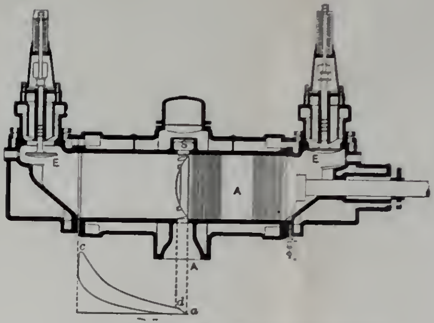


The new gear of the Nürnberg Company.

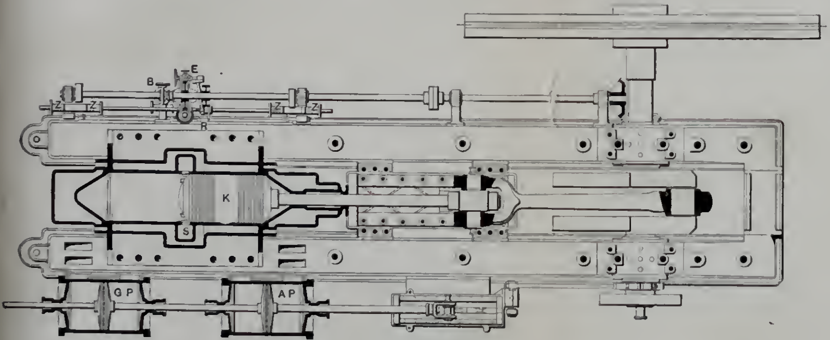
PLATE II.—NÜRNBERG COMPANY'S VALVE GEAR.



Plan showing method of working.

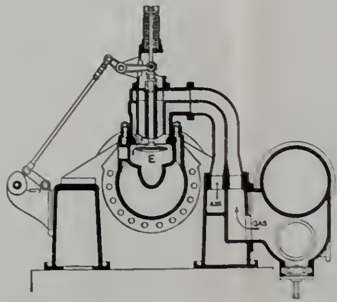


Longitudinal section through working cylinder.



Horizontal section.

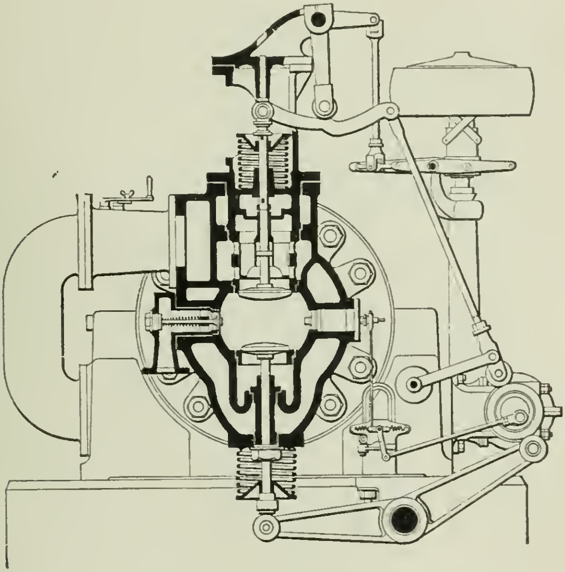
P, piston in working cylinder; *S*, exhaust ports; *G P*, gas pump; *A P*, air pump; *E*, adjustment device for igniter; *B*, valve for admission of compressed air for starting engine.



Cross-section through admission valve.

PLATE III.—KOERTING DOUBLE-ACTING, 2-CYCLE GAS ENGINE.

The gas and the inlet valve are combined with a piston valve for the admission of air in the same casing and are mounted on the same spindle. When the valve spindle is pressed down by the gear mechanism, the inlet is first opened and the air valve and the gas valve follow a moment later, opening inward or downward. A powerful spring closes them. One end of the valve lever is attached to the valve spindle, the other end seizes a rod driven from the gear shaft. The support of the valve lever is a roller.



Single-acting Deutz 4-cycle gas engine. Section through cylinder head.

When the driving rod is lifted, the valve lever presses against the roller and the inlet valve is forced downward. When the driving rod descends, the valve is gradually closed. The arrangement is so made that the valve opens with the beginning of the suction stroke and closes toward the end of that stroke. The roller is borne by a lever which oscillates on a shaft acted upon by the governor, and the valve lever is so shaped and so arranged that its upper surface, when the valve is closed, forms a circle tangential to the roller circumference, the center being the center of the shaft operated by the governor. When the governor by a turn of the shaft changes the position of the roller, the valve is kept open for the same period of time as before, only it is opened more or less. The regulation, therefore, amounts to throttling the supply of gas and air mixture by simultaneously changing the sections of the gas and air passages. The mixture remains the same, only a larger or smaller quantity enters the cylinders. The exhaust is opened by a cam. The igniters are also shown.

One of the latest four-cycle engines designed is that of the Vereinigte Maschinenfabrik, Augsburg, und Maschinenbau Gesellschaft, Nürnberg, Actiengesellschaft, which we may refer to as Nürnberg for short. The general design is shown in accompanying views of a 350 horse-power twin gas engine for the Rostock electrical station. (See Plate I.)

The Nürnberg Company has a number of valve gears, the latest being shown on Plate II. On the shaft is a cam *a*, which, through the rod *d e*, actuates the inlet valve through the intermediary of the lever *e f g*. This valve opens inward during the whole of the suction stroke. It is closed by the spring F'. In the same valve case is a nearly counterbalanced doubly seated valve, which permits the entrance on the one hand of gas and on the other hand of air in constant proportions. It is operated through the intermediary of the forked lever *m f l* and the inner rod *l k i*. The roller *i* of this rod is in contact with the surface of the lever *c b*, so that this mixture valve is also opened during the entire suction stroke.

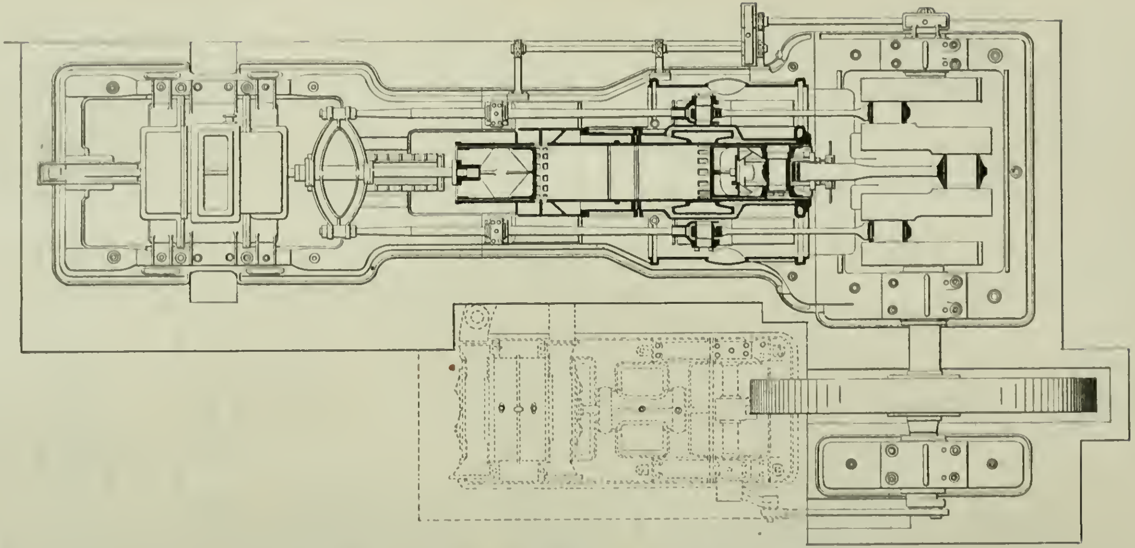
The governor acts by displacing the rod *l i*, so that the roller *i* is more or less distant from the fulcrum *c*. In this manner the mixture valve opens more or less according to the position of the governor.

A somewhat different design of the valves of the Nürnberg Company is that adopted for the engine installed at the Rheinische Stahlwerke at Meiderich, which is the largest single-cylinder machine thus far built, and which, according to private advices, is doing particularly effective work. (Plate II.) There are two sets of inlet and exhaust valves, the former lifted by cams. A fifth valve is connected through short ports with both inlet valves, and it is this valve which is controlled by the governor through a latch motion similar to that of many steam engines. The governing is therefore done by quantity with constant mixture and by variable compression.

In one respect the most interesting of the European gas engines, to the American iron makers, is the Koerting double-acting two-cycle engine, because it has been selected as the most suitable by the engineers of the Lackawanna Steel Company, the pioneers in this country. The piston has a length about equal to the stroke of the engine, while the working cylinder has somewhat more than double its length. At both ends of the working cylinder are the inlet valves, which are operated by cams from the valve shaft. Besides this valve there is attached to the cylinder head only the small valve for starting the engine with compressed air. The engine has no exhaust valves. The working piston, when it occupies the position at the end of the stroke, uncovers a series of ports through which the products of the combustion may escape. (Plate III.)

In the Koerting engine the mixture of gas and air is supplied by two auxiliary pumps, located alongside the working cylinder. They are driven by a crank from the main shaft, and are operated by one rod. They are supplied with plain piston valves, so arranged that the rear part of the gas pump and the rear part of the air pump supply the rear inlet valve of the engine cylinder.

In order to explain the method of operation of the working cylinder, we will assume that the piston occupies the rear end of the cylinder. The explosion takes place and the piston moves to the right until it clears the exhaust ports, as it is about to do in the engraving. The products of combustion escape and the pressure rapidly drops. In the meantime the pump pistons, which are traveling in the opposite direction, force air through the pipe line to the inlet valve. The compressed air expels the gases of combustion, cools the cylinder and forms a separating layer between the gases of combustion and the fresh mixture which now enters the inlet valve. Both the air and the gas pistons



Oechelhaueser 300 horse-power gas motor, driving blowing engine.

are delivering into the rear part of the main cylinder, in the case of the gas, through the ports *b* and *a*. In the meantime a charge has been compressed in the forward end of the working cylinder. The returning main piston compresses the fresh charge in the rear end and the cycle repeats itself.

The gas pump is supplied with two throttle valves, *f f*, so placed that when they open they connect the cylinder port *b* with the gas delivery line *k g*.

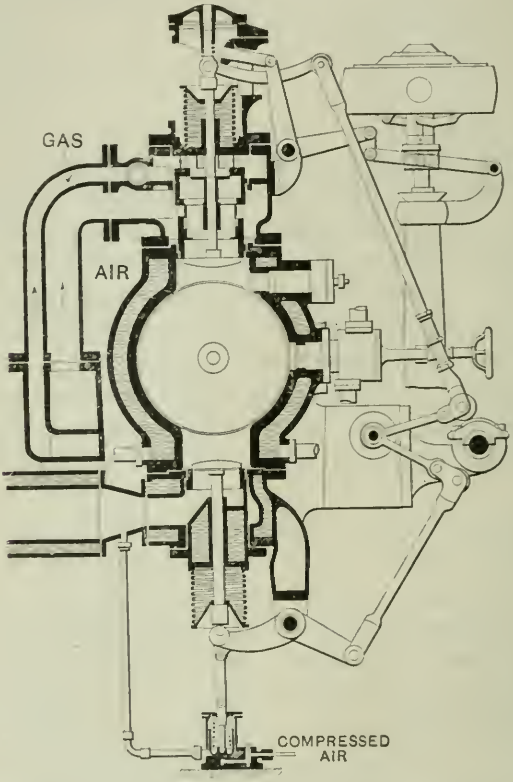
To begin with, however, let us assume these valves to be closed.

The air pump is so operated that the air piston valve cuts off the air cylinder from the air supply at once after the end of the suction stroke, and immediately afterwards connects it with the air pressure line to the working cylinder. When, therefore, the piston makes its return stroke the air in the pressure line is compressed until the inlet valve of the working cylinder is opened by the gear. In the meantime the arrangement of the gas pump is such that it does not deliver. For a while only compressed air enters the working cylinder, and it is only later that the pressure in the gas line reaches a point, when mixture also is introduced.

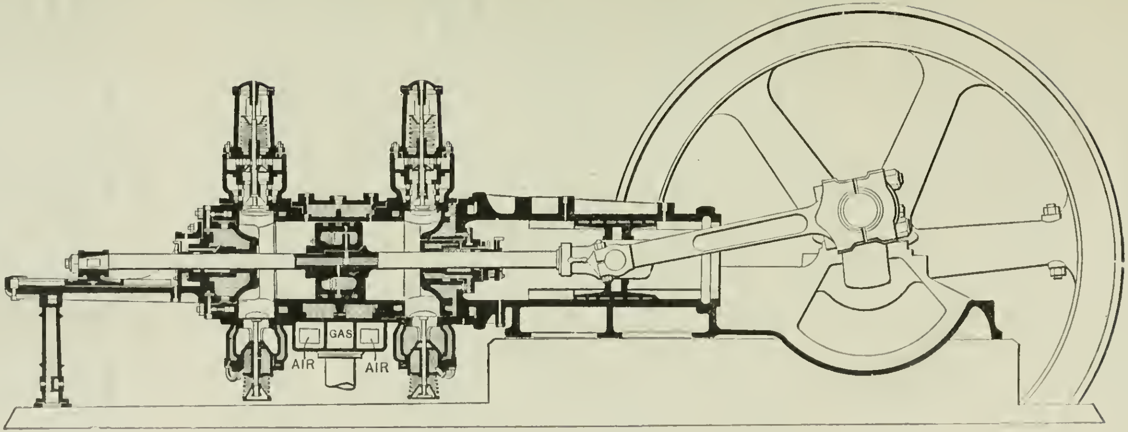
The throttle valves *f f* have been introduced in order to lessen the supply of gas in case that the load varies. When they are not completely closed there is a constant connection between the gas pump and the gas line to the main engine, and the leakage thus purposely brought about delays the delivery of the gas into the working cylinder.

An entirely different type of engine is the Oechelhaueser, the operation of which may be described by reference to the accompanying view, which shows the plan of a 500-horse-power motor driving a blowing engine. The cylinder is equipped with two pistons and the engine has no valve gear whatever.

When the two pistons are closest to one another the space between them is filled with a compressed mixture of gas and air. On igniting it the pistons are driven asunder. At first the forward piston uncovers a ring of slits in the cylinder. At this moment the exhaust of the gases of combustion begins. Soon afterward the rear piston opens a second series of slits on the opposite end of the cylinder, through which air compressed to 0·3 to 0·4 atmosphere enters and takes care of the complete expulsion of the residual products of combustion. Then follows a third ring of slits. In the older designs a mixture of air and gas was forced in through these. In the more recent designs it is only gas, so that now the mixture is made in the cylinder proper. Since the exhaust slits open earlier and remain open longer than the gas intake slits there might be some fear that the gas mixture might be blown through. This is improbable, because in normal working a volume of mixture equal to only 70 per cent. of the piston displacement is used. When



Deutz double-acting 4-cycle gas engine. Section through cylinder head.



Deutz double-acting 4-cycle gas engine. Vertical section.

the return movement of the piston starts, the slits are covered one by one, the mixture is compressed to 8 to 10 atmospheres and the operation begins anew.

The Deutz Company are building a double-acting four-cycle gas engine which seems well designed. At each end of the cylinder an inlet mixing valve is combined on one spindle with the gas and the air valve. The water cooling is thorough, and an effort has been made to relieve the pressure on the valve shaft during the lifting of the exhaust valve by the use of compressed air.

It is a horizontal engine with a water-cooled cylinder open at one end. To its rear is bolted a cylinder head, in which is arranged above the inlet valve, and below the water-cooled exhaust valve, the maximum size of the cylinders for larger units being 250 to 300 horse-power.

The selection of the system most suitable for particular purposes is still a difficult one. The experience accumulated is hardly sufficient and the changes in design have been frequent. The ordinary four-cycle engines do not, on the whole, run as regularly as the double-acting engines and their size is great. They appear to have, however, a higher mechanical efficiency. We are still in a period of active evolution. Thus far preference seems to be given in Europe to the open double-acting four-cycle engine for smaller powers, say from 300 to 400 horse-power. For larger machines the double-acting four-cylinder engines and two-cycle engines are recommended. For very large powers, up to 1,000 horse-power per cylinder, those engines which have no exhaust valve, that is, two-cycle engines, are recommended.

PLUMBAGO PACKING-RINGS.

It has been suggested that plumbago packing-rings of special design could be profitably employed in superheated steam engines, gas engines and other heat motors in which a high temperature is employed. Plumbago or graphite is unaffected by heat and is capable of being molded into permanent form suitable for packing-rings, which are now uniformly made of metal. The chief expected advantage is the mirror-like surface and polish that such rings would impart to a cylinder.—*Iron Age.*

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, April 15, 1903.

Safety Mining Lamps.

By Rufus J. Foster,
Mining Engineer, Vice-President International Correspondence Schools.

The necessity for safety lamps in coal-mining operations is due to the presence of light carbureted hydrogen, CH_4, or marsh gas, in the mine atmosphere. This gas is generally designated as "fire damp" by the miners. It rarely happens that the gas is found in a pure state in the mines. It often contains admixtures of other gases, such as carbonic-acid gas, CO_2, and carbonic-oxide gas, CO.

The term "fire-damp," as used by miners, means also such an admixture of light carbureted hydrogen and air as will form an explosive mixture. Pure marsh gas, or light carbureted hydrogen, is colorless, odorless, and tasteless, and is lighter than air. Its specific gravity is ·559, and it diffuses rapidly in the air and forms a "fire-damp" mixture. It burns with a blue flame, but will not support combustion. Pure marsh gas, or light carbureted hydrogen, is not poisonous, but it will cause suffocation, because it excludes oxygen from the lungs.

Owing to its light specific gravity, marsh gas, or the fire-damp mixture, always lodges against the roof of a mine, or seeks the higher places. It has been a serious and dangerous obstacle to the mining of coal since the very infancy of the industry.

As stated previously, pure marsh gas, when present in small quantities in the air, burns in the flame of a lamp without explosion. As the quantity of the gas is increased, the effect on the flame of the lamp is at once noticeable. As the proportion of gas in the air is further increased, and approaches the lower explosive limit, the lamp flame enlarges, snaps and crackles. When the proportion of gas to air is 1 to 13, slight explosions occur within the lamp, the flame of the lamp jumping violently. As the proportion of gas is increased, the violence of the explosion is augmented, until it reaches a maximum when the proportion of gas to air is 1 to 9½ (exactly 1 : 9·38). This is the proportion of gas and air in fire-damp when at its maximum explosive point. From this point, as the quantity of gas is still further increased, the violence of the explosion decreases, until it becomes very feeble when the proportion of gas and air is 1 to 5½, and ceases altogether beyond this point. These limits refer to a fire-damp mixture, consisting of pure marsh gas and air.

For many years the European coal miners regarded explosive gases in mines as supernatural manifestations and as expressions of the displeasure of the goblins at man's presumptuous invasion of their domains. The same idea prevails in China to-day, and it is still a common practice in that country to abandon a coal mine after an explosion, for fear of further angering the dragon spirit.

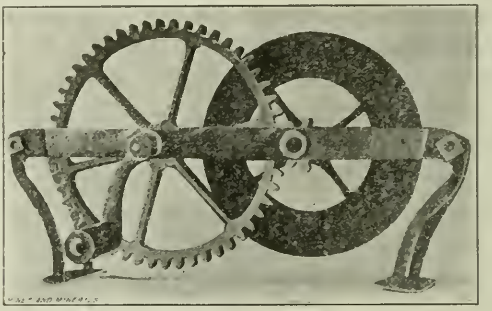


Fig. 1.

An examination of the mines before the miners went in to work was practiced in England in a very crude way as early as the middle of the fifteenth century. A dog lowered down the shaft would howl when it entered the fire-damp and it was then withdrawn and the gases cleared away by running a brush tied to a rope up and down the shaft. In Staffordshire a fire boss is still called a doggie.

Candles and various forms of lamps were early used for lighting the mines, and when the working places became so foul that such lights could no longer be used, skins of putrid fish were hung up and their slight phosphorescence enabled the miner to barely make out the face of the coal. This custom probably suggested the idea of using luminous paints in the mines, tried subsequently, and it developed later into the present very common practice of whitewashing portions of the mine to aid in the illumination.

By the year 1800, steel mills, *Fig. 1*, had come into general use in England for lighting mines, and, though safer than candles, many explosions resulted from their use. The illustrations, *Figs. 1* and *2*, were made from photographs of a steel mill used in English mines as early as 1766.

These mills were operated by boys, usually the sons of the miners, each miner taking his boy into the mine and requiring him to almost continually turn the wheel with one hand while he held a piece of flint against the wheel with the other, as shown in *Fig. 2*. The resulting shower of sparks, while a beautiful pyrotechnic display on a small scale, gave but little real light.

During the early years of the nineteenth century the ever-recurring disastrous explosions throughout Great Britain made a great impression upon the Rev. John Hodgson, a clergyman of the North of England. At that time the newspapers did not publish accounts of explosions in the mines, and they were given as little publicity as possible, so as to avoid giving offense to the colliery owners. The Rev. Mr. Hodgson, however, in the face of public opinion, gave an account of a serious explosion which occurred at the Felling Colliery, May 25, 1812, by which ninety-two men and boys were killed, and after this in every possible way he directed public attention to the subject of mine accidents.

These public notices attracted the attention of Mr. J. J. Wilkinson, a Barrister-at-Law of London, through whose efforts the "Society for the Prevention of Colliery Accidents" was formed October 1, 1813. Soon after the formation of this society, the assistance of Sir Humphry Davy was solicited to solve the problem; but the letter inviting his assistance miscarried, and it was not until three years later that the matter was brought to his attention. Sir Humphry at once reviewed all that had been written on the subject, and then visited the mines of the North of England, where he studied the practical considerations connected with the use of lamps about the mine and consulted with mine operators. Mr. Hodgson made known to him a theory that the fire-damp came from the coal itself and not from the decomposition of the coal or the water or of the pyrites, as was commonly supposed. Sir Humphry Davy immediately went into the dining-room of Mr. John Buddle, with whom he was staying, and broke some pieces of coal under water, when gases were seen to bubble up through the water, thus showing that Mr. Hodgson's ideas were probably correct. Sir Humphry next visited Dr. Clanny and inspected a lamp he had made; then returned home and immediately began his experiments, which from the first were encouraging. He soon discovered the action of wire gauze upon a flame, and early in January, 1816, only about five months after he began his investigations, sent three "Davy's" to Newcastle, where they were first tested at the surface and then underground, and during the same year they came into general use throughout the North of England. Although, of course, modified in its details, the present Davy lamp is entirely similar to these first sent out by Sir Humphry Davy.

Although Sir Humphry Davy invented the first practical safety lamp, the honor of first suggesting a method for insulating mine lights belongs to Dr. Clanny, a physician of Sundaman, England. Late in the year 1811, or early in 1812, he constructed a small lamp of strong glass, the bottom of which was closed with the exception of a small opening to admit air to the enclosed candle, the necessary amount of air for combustion being furnished by bellows. He afterwards, also unsuccessfully, tried a lamp insulated by means of valves, but at last he succeeded in making a perfectly insulated lamp by passing the air from the bellows through a stratum of water below the flame, while the products of combustion escaped through a stratum of water above. Although none of these lamps came into practical use, Dr.

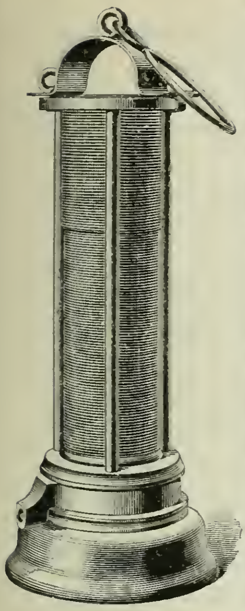


FIG. 3.

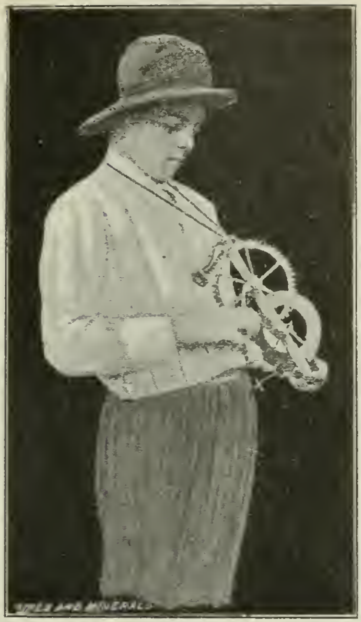


FIG. 2.

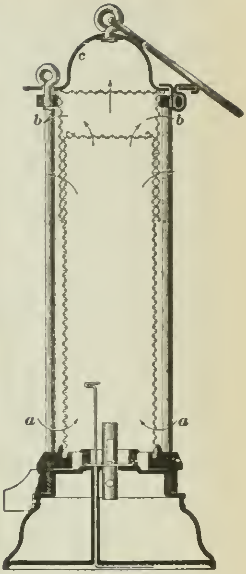


FIG. 4.

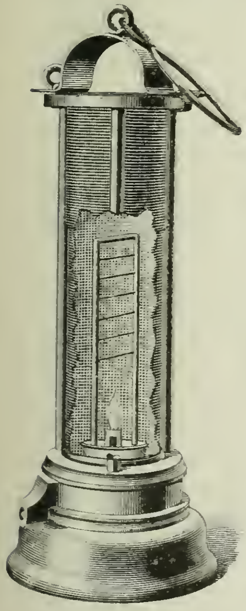


FIG. 5.

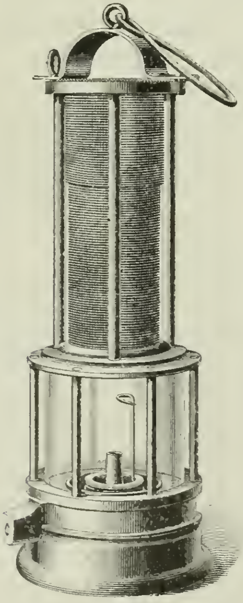


FIG. 6.

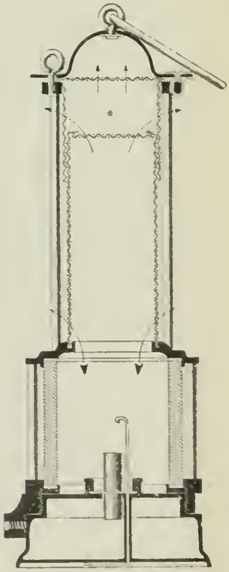


FIG. 7.

Clanny is entitled to the credit for conceiving and first carrying out the idea of constructing an insulated lamp.

Mr. George Stephenson, from the North of England, also invented a safety lamp, and his friends have at various times claimed priority for his invention over that of Sir Humphry Davy. The records seem to show that while Mr. Stephenson undoubtedly invented a safety lamp, this lamp was no more of a practical success than were the several lamps of Dr. Clanny, until after Sir Humphry Davy had made public his discovery of the cooling action of wire gauze, which principle Mr. Stephenson then applied to his lamp. The question of priority of discovery of the cooling action of a gauze or thin plate is still an open one. After Dr. Clanny had tried both the Davy and the Stephenson lamps, he improved the illuminating power of the Davy by surrounding the light with a glass cylinder.

While the Davy and Clanny lamps of to-day are practically the same as those first produced by Sir Humphry Davy and Dr. Clanny, all other types are combinations and adaptations of the principles of the two, with certain modifications. The general principle involved in the construction of a safety mining lamp is the isolation of the flame from an explosive atmosphere. A flame is a stream of vapor or gas made luminous by heat, usually the heat of its own combustion. As it requires a temperature of 1,220° F. to ignite marsh gas, it is essential that a gaseous atmosphere must be kept from such heat, or, conversely, that such heat must be kept from the gas.

The proximity of any cooling surface whatever to a flame has the effect of reducing the temperature of the burning gases, and the flame is extinguished thereby. This may be shown by presenting a flame to any cold surface, when it will be seen that the flame does not touch the surface. It is separated from it by a thin layer of gas that does not burn, because it has been cooled below the point of ignition. This will continue as long as the surface remains cool.

In the case of a flame impinging against a cool wire gauze, or other perforated surface, the conditions are very favorable for the cooling of the gases of the flame below the point of ignition. As they pass through the small openings, the gases are divided into minute streams or jets by the meshes of the gauze and cooled instantly, being thereby extinguished. It was this fact that Sir Humphry Davy discovered and which led him to the conclusion that if a lamp flame could be surrounded by an iron gauze it would be prevented from spreading to the surrounding gases. The discovery of this principle at once led to the surrounding of the flame of an ordinary lamp by a metal surface having numerous apertures. Davy made use of the wire gauze for this purpose, while George Stephenson employed a metallic surface punched with numerous small holes. The principle of the isolation of the flame by means of a cold metallic surface, while the light of the lamp was permitted to pass through small apertures, is the same in each of these, but the gauze employed by Davy gave the better light. His experiments showed that a fine wire gauze, composed of wire $\frac{1}{40}$ to $\frac{1}{60}$ inch in diameter, having 784 openings to the square inch, formed by crossing twenty-eight parallel wires, would not permit the flame to pass outside the lamp. By enclosing the flame of an oil lamp within such a gauze, it is surrounded by a safety shield. When the lamp is placed in an explosive mixture, the gas inside the gauze is ignited and burns, but the flame of the burning gases inside the lamp cannot pass through the gauze to ignite the gases outside the lamp, as long as the gauze remains cool.

In the extraction of the coal the miner is exposed to all the dangers incident to a gaseous atmosphere, with which he is continually surrounded. These dangers are twofold in their nature: (*a*) The danger arising from an explosion of mine gas due to its ignition by the flame of a naked lamp or of a blown-out shot, or the sparking of an electric wire or other cause; (*b*) the danger arising from the poisonous effects of many of these gases, or from suffocation because of their inability to support life. It is the first of these two classes of dangers that we consider in reference to the safety lamp.

Safety lamps may be divided into two general classes, according to the uses for which they are to be employed:

(1) Lamps for general use at the working face.

(2) Lamps for testing for gas.

There are some lamps that are designed for general use only, others are designed for the purpose of testing for gas only, while still others are constructed so that they may be employed for both purposes. A lamp, however, that is very sensitive to the presence of mine gas, and thus possesses one of the most important requirements for testing for gas, does not make a good lamp for general use at the face, for the reason that it will require too much watching on the part of the miner in order to avoid the possibility of the flaming of the lamp. On the other hand, a lamp that possesses all the requisites of a good lamp for general use is not adapted to testing for gas.

The following may be stated as the requisites for a good lamp for general use:

(*a*) Maximum illuminating power.

(*b*) Safety in strong currents.

(*c*) Simplicity of construction.

(*d*) Security of fastening or lock.

(*e*) Minimum liability to flaming and internal explosion.

The requirements of a good lamp for testing for mine gas are:

(*a*) Sensitiveness to small percentages of gas.

(*b*) A small, uniform, non-luminous flame.

(*c*) Free entry of air into the lamp below the flame.

(*d*) Drawing gas into the lamp from a thin layer at the roof.

These several requirements are attained by several different forms or types of construction. The illuminating power of the lamp is increased by as free an entry of air into the lamp as possible. The entry of the air should preferably be at a point below the flame; but when the air enters the lamp above the flame a deflector is often used to separate the ascending and descending air-currents, so as to prevent the smoking of the lamp. The illuminating power is also increased by increasing the draft of the lamp, which is accomplished in the Mueseler lamp by a wrought-iron or copper conical chimney placed within the lamp gauze imme diately above the flame. Safety in strong currents is secured by bonnets placed outside of the gauze, or by simple gauze chimneys, as in the Marsaut lamp. Simplicity of construction is important for purposes of thorough and rapid cleaning. There are several forms of lock in use, most common among which are the lead plug lock, and the ordinary turnbolt requiring a simple split key. More recently magnet locks have been introduced, as in the Wolf lamp, that can only be opened by means of a strong magnet. These, perhaps, furnish the greatest security.

The liability to flaming is largely reduced by a good circulation within the lamp. Security against internal explosions is obtained by means of multiple gauze chimneys and also by metal bonnets. The sensitiveness of the lamp, and its power to detect small percentages of gas in the mine air, which makes it valuable for testing, is secured largely by the free entry of air into the lamp at a point below the flame. This is best attained in the simple Davy lamp, which has always been a favorite with fire bosses.*

The Davy lamp is shown in *Figs. 3* and *4*. The style shown is the lamp used by working miners. There are several different forms of the Davy lamp, but they differ only in size and in the shape of the oil cup. In *Fig. 4* the arrows marked *a* show the ingress of the air to support combustion, and the egress of the products of combustion is shown by the arrows at the top. There is a double gauze at the top formed by a gauze cap over the main gauze; this is shown by the letter *b*. The gauzes are held in place by the hood *c*, which is hinged and clamped in place by the eyebolt shown just above *b*. The principal use of the gauze cap is to prevent the liability of the gauze being burned through at the top. As shown, the air enters the lamp freely through the gauze, all around the flame, and passes out through the upper part of the cylinder and the gauze cap.

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* To illustrate his paper, Mr. Foster had on exhibition a collection of forty-two different safety lamps, part of the collection of the School of Coal Mining of the International Correspondence Schools. As it is impracticable to illustrate all of them in the JOURNAL, only such as are distinctive in type are shown in the illustrations.

This free passage of the air into the lamp at a point below the flame insures a good flame cap for testing purposes. The lamp, however, flames easily, and when unbonneted is not safe in a current whose velocity is greater than 6 feet per second, as the flame in the lamp is liable to be blown through the gauze. When used by a fire boss for testing purposes, the flame is turned low by use of the hooked wire picker shown in the sectional view. The lamp is then carefully lifted toward the roof of the mine. If there is gas present in small quantity a cap or halo shows on top of the flame. If in larger quantities, the gas burns with a blue flame inside of the gauze. When the presence of gas is thus shown, the fire boss carefully and slowly lowers the lamp, until it is either below the stratum of gas and retreats with the lamp held near the floor, or he puts it under his coat and extinguishes the flame inside the gauze by smothering it, and he retreats in the dark.

The most recent improvement in the Davy lamp for testing purposes is the Beard-Mackie safety-lamp attachment. It is the joint invention of Prof. J. T. Beard, Principal of the School of Coal Mining of the International Correspondence Schools, and Matthew D. Mackie, an experienced fire boss in the employ of the Delaware, Lackawanna and Western Company. It is a sight detector of simple design and can be used in almost any testing lamp. It consists of an iron or brass rod so bent that it forms two parallel legs of any required length, and from ¾ inch to 1 inch apart. The two ends of the rod are soldered to a brass ring which fits down over the burner of the lamp, and which is held in place by any kind of a set-screw or clamp, and the two legs extend perpendicularly into the lamp to the desired height. Strands of fine platinum wire, at regular distances, are stretched horizontally from one leg to the other. This makes a miniature ladder with brass or iron sides and platinum-wire rounds. The lower strand is arranged at such a height as to be just at the point of incandescence when the lamp is in pure air. The successive strands above this are arranged at such heights as will indicate the percentage of gas, if that is desired, or less accurately for practical testing purposes, to show danger points. The practical value of the device lies in the latter feature, and the fact that it readily shows the relative explosiveness of the mine air, and the fluctuation in the amount of gas present.

This device is shown in *Fig. 5.*

In testing for gas, a reduced flame in the lamp is used, and the heights of the wires must in such cases be adjusted accordingly, and they will be equally as effective as when a normal flame is used.

On account of the sensitiveness of the platinum wire, due to its absorption of the gas, it becomes incandescent at a much greater height than is reached by the flame. In the use of a flame $\frac{3}{4}$ of an inch in height, the strands will glow brightly to a height of $1\frac{1}{4}$ inches above the tip of the luminous flame when 2 per cent. of gas is present.

This appliance has been unanimously endorsed by the Association of Fire Bosses of the D., L. & W. mines. I recently saw a demonstration of its action when used in a Davy lamp in a gaseous atmosphere, and I was particularly attracted by the positive, sharp manner in which the incandescing of the successive wires indicated the increasing percentages of gas, and also with the fact that the lower wires were brightly incandesced by so small a percentage of gas as would hardly show a perceptible cap on the flame.

There are as many, if not more, forms of the Clanny lamp than of the Davy. All of them are, as in the case of the Davy, simple modifications of the original lamp. The characteristic feature of the Clanny lamp consists in the substitution of a strong glass cylinder for the lower part of the gauze cylinder of the Davy lamp. In other respects it is the same as the Davy lamp. The entry of the air in the Clanny lamp, however, takes place above the glass cylinder, *Figs. 6* and *7*, the entering air descending inside of the lamp to the flame. This gives rise to conflicting descending and ascending air-currents within the lamp, which often produce a smoky flame. This feature of the Clanny lamp impairs its illuminating power, as the glass cylinder becomes smoked and the flame itself is not as bright, owing

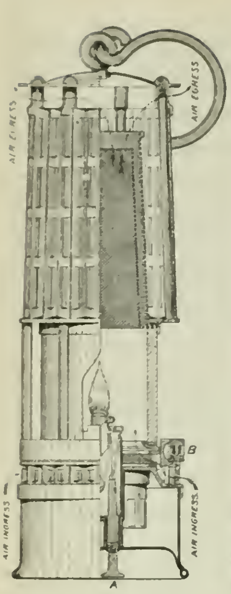


Fig. 8.

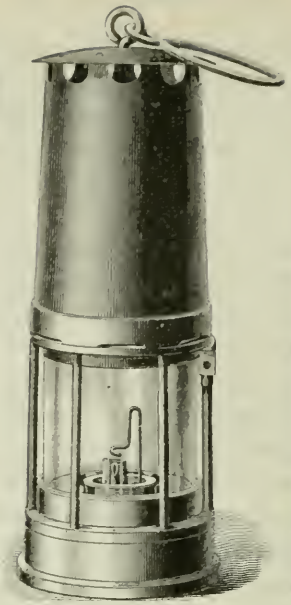


Fig. 9.

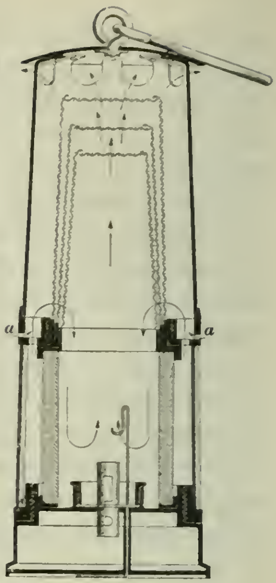


Fig. 10.

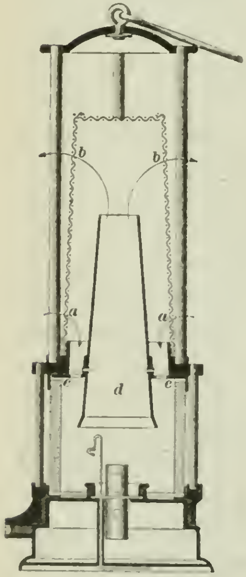


Fig. 11.

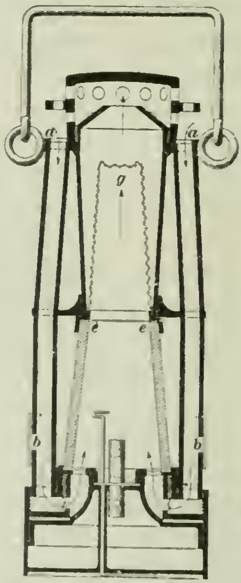


Fig. 12.

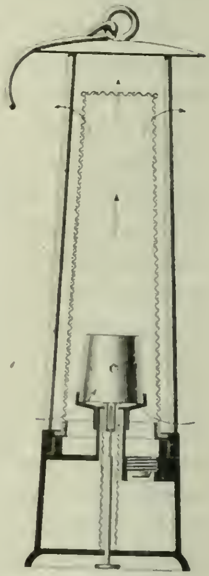


Fig. 13.

to insufficient draft. The lamp does not present the conditions favorable for testing for gas, the lamp flaming readily in a body of fire-damp, and the flame not being sensitive to small percentages of gas. This lamp is also made in brass and aluminum, and with various forms of lock fastenings and oil vessels.

The unbonneted Clanny lamp is not safe in a current of air having a greater velocity than 8 feet per second. One improvement which tends in a slight degree to obviate this fault is a small iron or copper shield about 1 inch in width surrounding the lower part of the gauze immediately above the glass cylinder. While this is a slight improvement, it is not as effective as the bonnet, which completely covers the gauze cylinder, except that means are left for the egress of the products of combustion near or at the top.

The Wolf lamp is one which has met with practically unanimous approval from mine managers both in this country and in Europe. It is the invention of Mr. C. Wolf, of the firm of Friemann & Wolf, of Zwickau, in Saxony. The lamp shown in *Fig. 8* is the latest type of the Wolf lamp. It was evolved from the Clanny lamp.

The chief characteristics of this lamp are : (1) The adaptation of the oil cylinder for burning naphtha, thereby greatly increasing the illuminating power and the sensitiveness of the flame ; (2) the introduction of an ingenious igniting arrangement, which permits the miner to relight the lamp without danger in case the flame is either accidentally extinguished or has been extinguished by gas burning inside the gauze ; (3) a magnet lock or fastening which prevents any tampering with the lamp by the miner. The lock can only be opened by the use of a very strong and heavy magnet at the surface or lamp station.

At first the idea of the use of so volatile an illuminant as naphtha prejudiced many mining men against this lamp; but the method of using the naphtha, and the use of an automatic lamp filler overcomes all the objections. The naphtha in the oil chamber is held in an absorbent material, and the flame is fed from the volatile gas arising therefrom. The flame is a particularly bright one, and has about double the candle-power of the best safety lamps of other types. The cost of the naphtha is about one-quarter that of the oil used in other lamps. The Wolf lamp is essentially a working lamp, and is not intended for testing purposes. It will show the presence of gas in the air when the percentage is as low as 1 per cent., but it will invariably go out before the mixture of gas and air reaches the explosive point.

The manner in which the lamp takes its air is shown on *Fig. 8*. It enters in a tortuous way through port-holes below the flame, passing through a gauze ring before it enters the lamp, and the products of combustion find egress from the top of the double conical gauze chimneys, as shown by the arrows. The gauze chimneys are protected by a bonnet, which completely surrounds and extends above them. This bonnet is fluted and contains a number of port-holes, which are so arranged that an air current blowing against the lamp cannot find direct ingress. The thumb-screw, by means of which the igniter is operated, is shown at *A*, and the magnetic lock at *B*. This lamp has been proven capable of withstanding an air current with a velocity of more than 59 feet per second. Its value as a safe lamp is attested by mine officials and mine inspectors, and it is so highly esteemed that the Bituminous Mine Law of Pennsylvania, which formerly strictly prohibited the taking of volatile oil into a bituminous mine in Pennsylvania, was, at the request of mine officials and mine inspectors, amended in 1901 to read: "No volatile oil, *except when used in approved safety lamps*, shall be taken into any mine," etc.

These lamps are made of various metals, including aluminum alloy, the latter material making an exceedingly light-weight lamp.

Messrs. Friemann & Wolf have just placed on the European market a new lamp known as the Wolf-Stuchlik lamp. This lamp retains the general form of the Wolf lamp shown, but the oil chamber, instead of being constructed for the use of naphtha, is constructed as an acetylene lamp. This lamp will give a light equivalent to 7 candle-power, as against $\frac{6}{10}$ candle-power of the best oil-burning safety lamps, and the 1 candle-power of the Wolf naphtha lamp. There is a horizontal reflector affixed to this lamp, which, when so desired, reflects the light against the roof; the upper frame of the lamp and the handle by which it is carried being so arranged as not to interfere with the rays of light. This lamp has not as yet reached this country, and I am merely giving a brief statement of a written description of it which I have seen. That it gives increased light without increased danger, and that by its use the mine-roof can be inspected, are features of great value.

The Marsaut lamp is similar to the bonneted Clanny lamp in every respect, but is supplied with three gauze chimneys as shown in *Figs. 9* and *10*. It is a peculiarly strong lamp in this respect, as the security against explosions of gas within the lamp is thereby increased. This lamp is often extinguished in an explosive mixture by the force of the explosion within itself. It gives a good light and is a good lamp for the working miner. The Marsaut lamp has been improved by the addition of a deflector known as Howat's deflector. This consists of an annular ring placed about 1 inch above the top of the glass cylinder, and so as to fill the annular space between the bonnet and the gauze. Resting on top of the cylinder, and extending almost up to this annular ring, is a metal diaphragm which serves to deflect the entering air down upon the flame. This greatly increases the illuminating power of the lamp.

In the Mueseler lamp, *Fig. 11*, the attempt was first made to increase the draft, and thereby improve the illuminating power and prevent smoking. The lamp is provided with a central conical tube or chimney *d*, of sheet iron, held in position by a horizontal perforated diaphragm of sheet iron *e*, *e*, at the junction of the gauze and glass cylinders. Air enters the lamp through the gauze *a*, *a*, and, passing through the perforations of the diaphragm *e*, *e*, is drawn down under the expanded mouth of the central chimney in close proximity to the flame, and passes out the chimney and through the gauze *b*, *b*. The draft of the chimney materially increases the illuminating power of the lamp, while the central tube adds very largely also to the security of the lamp against currents and inner explosions, the latter seldom being communicated outside of the lamp. It is not a lamp adapted to the detection of gas, but it is reported to have safely withstood a current of 100 feet per second. It does not flame as quickly as the Clanny lamp. This lamp is made with or without a bonnet.

The Ashworth lamp has the flame surrounded by a conical glass chimney, which at the top fits into a brass cap surmounted by a single gauze about 1½ inches in height, also conical in shape. This gauze is surrounded by a brass cylinder which is conical at the top and open. The entire upper part is encased by a brass shield perforated on the sides and top. The air and mine gases enter through these perforations, pass down through the standards connecting the brass shield and the lower part of the lamp, then through a narrow gauze about ½ inch high, placed directly beneath the glass chimney, and into the flame of the lamp. The hollow standards also have openings at the bottom, which are ordinarily kept closed by a slide, but the slides may be raised and the air thus taken from a point near the base of the lamp.

The Gray lamp is a Clanny lamp with the wire gauze of the upper half of a Clanny replaced by a solid metal chimney, which opens into a low cylindrical space surrounded by a wire gauze. The top of the lamp is perforated and protected by a horizontal wire gauze. All of the air enters from the extreme topmost point of the lamp, and is then led through four hollow standards connecting this top chamber with the base of the lamp into the combustion chamber below the flame.

The Ashworth-Hepplewhite-Gray lamp, shown in *Fig. 12*, is an improved combination of the Ashworth and Gray lamps. It is one of the best and most convenient of the lamps for testing for gas. When the lamp is being used for testing, the air enters the tops of the four standards, *a*, *a*, and passing down through the standards, enters the lamp below the flame, thereby producing the best conditions for yielding a good gas cap. The glass chimney, *c*, *c*, tapers toward the top, and the same conical shape is also given to the gauze chimney *g*, which is bonneted as shown. The conical shape of the glass assists the upward diffusion of the light, and makes the inspection of the roof easier, while the same shape in the gauze chimney renders the lamp more safe and secure against an inner explosion of gas being communicated outside of the lamp. The air being drawn into the lamp through the top of the standards makes it possible with this lamp to detect a thin stratum of gas near the roof. When not in use for testing, the air may be admitted at the bottom of the standards, at *b*, *b*, by moving a little shutter that closes them.

The wick of this lamp, when at a normal height, furnishes a flame of great illuminating power. When lowered by a fine screw adjustment, the flame becomes blue and non-luminous, and does not interfere, therefore, with the easy observation of a pale cap.

The Pieler lamp, shown in *Fig. 13*, has a gauze similar to a Davy lamp, but burns alcohol instead of oil. In its form, the gauze is bonneted by a sheet-iron bonnet, the gas caps being observed through a glass window. This window is very apt to become dimmed with smoke and moisture, thus impairing the observance of the caps. A shield *c* surrounds the flame, which is adjusted so that its tip does not extend above the top of the shield.

This lamp was designed by the inventor to yield a standard flame which would always present a certain height and volume, and yield flame caps of a uniform height for given percentages of gas. The following table was prepared by him to show the percentage of gas corresponding to different heights of flame caps, measured from the top of the shield *c*:

¼ per cent. of gas yields a cap 1·25 inches high.
½ per cent. of gas yields a cap 2·00 inches high.
1 per cent. of gas yields a cap 3·50 inches high.
1½ per cent. of gas yields a cap 4·75 inches high.
1¾ per cent. of gas cap reaches the top of the lamp, and beyond this percentage of gas the lamp fills with flame.

The lamp flames easily in a mixture containing more than 1¾ per cent. of gas, and is, therefore, dangerous, requiring great care and caution in its use. Any variation in the strength of the alcohol varies the height of the flame, which is, therefore, not strictly a standard flame.

The Dick lamp is another of the various forms of the Clanny lamp which have been introduced. The features of this lamp are the insertion of a rim of brass or zinc in the upper portion of the steel bonnet, for the purpose, it is claimed, of reducing the conductive power of the bonnet and cooling the lamp. Another essential feature of this lamp consists in the tangential position of the port-holes by which air enters the lamp through the bonnet. There are several rows of these port-holes extending around the bonnet and also the brass ring mentioned above. There is also a circular air box immediately above the glass cylinder, which is constructed to admit the air into the lamp through a separate gauze. This air supplies the flame of the lamp, while the air entering through the tangential port-holes in the bonnet serves the purpose of cooling the gauze chimney. It has never come into general use. The Derbyshire Clanny lamp differs from the ordinary bonneted Clanny, only in having a small inner bonnet at the top of the lamp for the more thorough protection of the openings at the top of the outer bonnet. The Garforth lamp is another type of the bonneted Clanny, from which it differs in no essential particular.

The Mauchline lamp is a simple unbonneted Clanny, in which the glass cylinder is replaced by a strong convex lens in one side of the lamp, while a reflector is placed in the opposite side. Between these, upon either side of the lamp, are small circular openings for the entrance of air, protected by gauze. It was designed for use in making mine surveys, but has only been used to a limited extent.

There are numerous modifications of the Clanny and Davy lamps, designed for the use of fire-bosses, besides those already mentioned and described. As they have not won even partial approval from mine officials, the writer does not think it well to enter into descriptions of them. In the collection of lamps they are simply curiosities.

The Marshall lamp has a conical bonnet, inside of which is a single gauze, this gauze being surrounded at the bottom by a second gauze and being connected at the bottom and on the inside to a metal deflector. The glass part of the lamp is entirely similar to the Clanny. Surrounding the glass chimney are five upright standards, one of which is movable up and down; by moving it downward, the upper part of the lamp can be locked to the oil chamber, and then by means of a hasp and staple the parts of the lamp are still further locked.

The Clifford lamp has a double bonnet, which is perforated to admit air. The lower part of the lamp very closely resembles the ordinary Clanny; but above the flame, and in place of the inclined metal chimney of the Mueseler lamp, is a bell-shaped glass chimney, like the lower part of an argand chimney. This fits into a metal tube, about which, at its connection with the argand chimney, is a double gauze, which completely insulates the flame chamber. This metal chimney opens at the top into a cylindrical chamber, which has a small opening at its top and across which is a gauze.

The Cosset lamp is a form of the Mueseler lamp, manufactured in France. In the ring, in which the lower ends of the standards rest, is a series of depressions or notches. A pin projects from the upper rim of the oil cup, and this pin is forced upward by a spring, but it can be withdrawn by turning a screw at the bottom of the oil vessel. This same screw also lowers the wick, so that when the pin is being withdrawn the wick is also being screwed down so low that the light will be extinguished. Desiring to use the lamp, the wick and pin are raised by turning the screw at the bottom of the oil vessel. The wick is lighted and the oil cup is then screwed into the top part of the lamp. It cannot be unscrewed as long as it is burning, because the projecting pin in the oil vessel catches in the depressions previously mentioned, which act like a ratchet, and to withdraw this pin also withdraws the wick and extinguishes the light.

The New Type Cosset lamp is a two-gauze Marsaut lamp of French manufacture. The upper rim of the oil vessel has teeth which form a rack. The glass cylinder of the lamp is surrounded by six standards. One of these standards is hollow and can be detached from the lamp. At either end of the detachable standard are projecting pins forced outward by springs within. One of these projections, when the standard is upon the lamp, passes down through the lower ring surrounding the glass and rests upon the rim of the oil cup. The upper projection contains a small hole, and this hole extends above the upper rim, which holds the standards. When the lamp is to be used the movable standard is placed in position, the wick ignited, and the oil cup screwed into the body of the lamp. A lead plug is then placed through the hole in the upper projection of the movable standard. In this condition the lamp cannot be opened, because the lead plug in the upper end prevents that projection from being depressed, so the standard can be entirely removed, and until that is done the lower projection catches upon the teeth of the rack on the oil vessel and prevents the latter from being turned.

The Cambessedes lamp is also a French lamp, having a broad circular base, hollow standards like the Ashworth-Hepplewhite lamp, and an argand burner like the Pieler. An extra oil reservoir extends half way around the glass cylinder. This oil vessel is made of a light-colored metal, and the side turned toward the flame is polished so as to act as a reflector. A circular disk of gauze fits over the top of the hollow standards, and is held in place by a circular plate, through the center of which a conical chimney is passed to within an inch or so of the wick. This chimney is surrounded by the usual cylinder of gauze, which extends to the top of the lamp. The air is always admitted through the circular disk of gauze at the top of the standards, passing down through them and up into the flame. The wick is raised and lowered by turning a thumb-screw at the side of the oil vessel. A wire passes through the bottom of the oil vessel to the wick, to remove from the latter all charred particles that adhere to it. This wire is held in its highest position by means of a hooked piece of metal soldered to the bottom of the oil vessel, under which the bent end of the wire is slipped. This prevents it from sliding down and becoming bent when the lamp is set down, a difficulty experienced with the wire "pickers" for raising and lowering the wicks, which are common in so many kinds of lamps.

All of the lamps described, except the Ashworth-Hepplewhite-Gray, the Pieler, and the Wolf lamps, are constructed to burn either vegetable or seal oils. Light mineral oils are burned in the three exceptions.

According to the English Mine Commission, the safest oils to use are vegetable oils, such as rape, made from rape seed, and colza, made from cabbage seed, and seal oil. None of these are explosive. Petroleum used alone is liable to explode, and should be avoided.

In point of brilliancy, the flame of a lamp burning seal oil is superior to one burning either rape or colza oil, and the wick is less liable to become charred.

By addition of one part of petroleum to two parts of rape-seed oil the light is increased.

Many of the oils in common use in safety lamps have a tendency to incrust the wick and thereby lower the flame. Petroleum or benzine added to the oil reduces this tendency and yields a better flame for testing purposes. Alcohol yields a hotter and less luminous flame and a much higher cap. In some cases, a hydrogen flame has been used for testing purposes. The hydrogen is compressed into a small steel cylinder attached to the lamp, and is burned in the lamp at the mouth of a small tube. This apparatus gives a standard flame for testing, but it cannot always be conveniently obtained.

PUPIN AND JENTSCH ON TRANSOCEANIC TELEPHONY.

Dr. Jentsch, of the German telegraph service, recently criticised Prof. Michael Pupin's system of long-distance telephony. His objections were leveled, not at the electrical features of the system, but simply at certain mechanical difficulties that might be encountered. In his opinion, external pressure of the water would increase with the depth to which a submarine cable was laid. At a depth of 2 or 3 miles it would not be impossible that a pressure of 3,000 pounds to the square inch would be found. From this Dr. Jentsch concluded that the inductance coils of Pupin, unless constructed with extraordinary strength, would be crushed in. Dr. Jentsch, however, as well as Professor Pupin himself, agrees that the difficulty is by no means insurmountable.

It has also been said that transatlantic telephony will not pay. Professor Pupin is himself of that opinion, not because of any inherent fault in his system, but because of the customs of the business world. A transatlantic telephone system would be used chiefly during the business day of six or seven hours. Since the day begins in London and Paris five hours earlier than it does in New York, it follows that only during a period of one or two hours would the line be in use. Professor Pupin's system, however, is equally adapted to the improvement of the submarine telegraph cable, so that its practical utility is by no means as curtailed as it might seem.—*Scientific American.*

DAMAGES CAUSED BY STRAWBOARD WASTE TO NATURAL WATER RESOURCES.

A serious damage to water resources, as well as to all vested interests along water courses in the United States, arises from the deposit of industrial wastes in streams that drain the manufacturing centers of the country. Among the wastes so deposited, that which is derived from strawboard mills is probably the most troublesome. -In the region north of Ohio River, where there are a large number of manufacturing plants of this character, the effects of strawboard waste have attracted great attention and have resulted in many suits at law for damages of one nature or another.

Strawboard waste is composed of small particles of straw, which, in the violent process generally used to reduce the stalks to their component cellulose fibers, are broken and ground to such a state of fineness that they readily pass out of the washing machine along with the waste water. This material is composed largely of the hard, glazed covering commonly observed on all straw stalks, and, as it contains a high proportion of silica, it is extremely difficult to treat or to utilize in a satisfactory manner. In addition to the straw particles there are varying quantities of waste lime and a fairly high proportion of extractive matter.

This waste mingles with other organic matter in a stream, and as a result there is produced a foul, reeking mass, which absolutely destroys fish life, ruins for agricultural purposes land which it overflows, unfits water for domestic supply, and is often highly damaging to residential property.

The United States Geological Survey has succeeded in enlisting the co-operation of several eminent authorities in the work of discovering the most practicable and economical means of purifying strawboard waste. Into this work the officials of the American Strawboard Company have entered with gratifying enthusiasm, and there is assurance that within a short time methods of disposal will be completed and adopted.

Experiments on the subject are being conducted at the Massachuset s Institute of Technology, Boston, Mass., under the direction of Prof. Wm. T. Sedgwick; at Earlham College, Richmond, Ind., under the direction of Prof. Robt. L. Sackett; and at Purdue University, Lafayette, Ind., by President W. E. Stone and Prof. Severance Burrage. These experiments are under the general supervision of Mr. M. O. Leighton, hydrographer, United States Geological Survey.

ELECTRICAL SECTION.

Stated Meeting, March 12, 1903.

Defective Machine Insulation.

By C. E. Farrington.

The best excuse for a forty-five-minute talk on the defective insulation which is found in modern dynamo and motor construction is the statement that it is the greatest obstacle to electrical development at the present time.

It is a fact beyond controversy that the electric motor is not being used as much as it would be if it were a more perfect machine.

A veteran railway superintendent, whose title was once "barn boss," recently told me how much he wished that he could have as little sickness in his motors as he used to have among the horses.

My connection with the manufacture of electrical insulation was brought about through the request of a large electrical manufacturing company for a substitute for shellac as an insulating varnish. This was some ten or twelve years ago, when all that any paint and varnish chemist knew about insulation was what he might derive from the examination of a dictionary; so we asked our electrical friends for full details of the work an insulating varnish had to do.

The answer, signed by one of the best known of the large construction concerns of a dozen years ago, is in my possession to-day, and reads: "An insulating varnish must contain as little water as possible and dry quickly. We cannot give you further details; but if you will make the varnish as above stated, we will make the tests to see whether it has any insulating properties."

If such an answer had been rendered on any other point concerning mechanical or electrical engineering, it would have been considered a glaring admission of ignorance, and no large electric company would have tolerated such ignorance after it had once exposed itself.

But it is a fact that electrical engineers have neglected to use the methods of applied chemistry in this most important item of their work. They have cheerfully gone on and on, jauntily ignoring well-known chemical law and trusting to the cleverness of their sales departments to shift to buyers the responsibility for losses and annoyances which might be wholly avoided were conscientious study made of the problem.

By our inquiry we finally ascertained that shellac varnish (gum 'lac dissolved in alcohol) gave the best results of anything which they had then used, but that electricians were quite well aware that it was defective. As no further information was forthcoming, we proceeded to make a very rapid drying copal varnish, which was duly submitted to our electrical friends, and after a few days' test it was adopted by them and its use commenced in considerable quantity. It was the first insulating varnish ever made.

As an illustration of what we have learned since then, I will say that no competent engineer will now concede that a given compound has any insulation value whatever until his tests have been those of actual service under widely different conditions and unless the time test is at least a year.

We submitted samples of our insulating varnish to several other electrical concerns, and invariably received flattering testimonials as to the wonderful insulating properties which it possessed. We gave it the name "Insullac," and I think during the next six months we unintentionally crippled as much machinery as we insulated. I think the record which we made at that time has been equalled once or twice since by some of our enterprising competitors. But in justice to them, I must say that they were guided by just the same sort of advice as we had.

The experience of that six months produced a profound impression. Savage complaints convinced us that the testimonials of our electrical friends were better testimony of their ignorance of the chemistry of insulation than of the quality of the material whose praises they sang. Our surprise and regret were superseded by an ambition to atone for our error, and we determined to learn something about the subject for the benefit of those whose injury we had unwittingly assisted in.

It is my pleasure to-night to outline the course of study which was opened by this investigation. It was primarily necessary for us to define the exact function of a varnish in and on the coils or windings of a dynamo electric machine. Why should a varnish be used at all? Solely because there has never been an insulating fiber produced which did not need some sort of reinforcement which could obviously be best applied in the form of a paint or varnish. Motors will not run, even in very dry situations, unless some protection in the shape of varnish is applied. When we asked electricians for an explanation of this, they told us that water got into the machines if varnish was not used. When this answer was applied to street-railway motors running on submerged tracks, or on motors unprotected from street spattering, the explanation seemed to be adequate, but its adequacy was completely lost when we applied it to stationary machines running under fairly good conditions.

It is perfectly obvious that if an unpainted generator armature should be saturated with water and then started up at full speed with the brushes lifted from the commutator, the centrifugal motion in a few moments would force out all moisture, and that then the brushes could be brought into contact and the load assumed without danger.

Surely the insulation resistance of the varnish is not required to enable the machine to run. There probably never has been a successful machine designed wherein the difference of potential between windings was equal to 10 per cent. of the insulation resistance of the ordinary double-cotton covering which was used on those windings.

This covering has a resistance equal to about 200 volts a.c., and it is obvious that if that resistance could be made constant, there would be no necessity for the reinforcement of machine insulation with anything in the line of paint or varnish. In other words, any paint or varnish which is used on magnet coils is used in the hope of making constant the initial resistance of the cotton covering.

It being plain that the function of any varnish or paint which is applied to a motor or dynamo coil is to reinforce the cotton covering, we must study the weaknesses of the cotton in order that we may know how to correct or help them.

The first defect of cotton is the fact that it cannot be spun to a commercial profit unless it carries from 5 per cent. to 15 per cent. of water; but at the same time our attention should not lose the fact that this water does not interfere with the average insulation value of cotton covering as indicated by mere laboratory tests. The trouble which the water makes is accomplished when it turns to steam under the heat of the machine or when it travels from the core out through the coil under the influence of rotary motion, leaving innumerable passages and openings where the electric current may follow.

Another material defect of cotton is the ease with which it becomes carbonized; but it is only fair to say that the carbonization of cotton covering is largely offset by the resistance gained from the expulsion of moisture as an armature becomes dried and seasoned.

The third defect of cotton is the acid which it carries and which assists its impregnation with copper oxide.

Determining that the best insulating material must be the one which would reinforce these weaknesses of cotton, we assembled all the materials commercially available for the manufacture of compounds which might be applied to coils of copper wire by dipping or with a painter's brush, and began the work of systematic search for the qualities which would enable these materials to accomplish the necessary results. In this connection every varnish gum, every treatment of drying oils, every combination of waxes, pitches, asphalts and gum substitutes, including the cellulose compounds, were brought under our tests.

The first test of all was to see whether a material had melting point or viscosity, or a combination of both, which would enable it to stay in a badly overheated coil. This point brought out a curious inability on the part of a good many electricians to distinguish a difference between old-fashioned tests and modern conditions.

They wanted to test insulation melting points by the same method by which oil chemists find the melting point of an oil or a wax, but we found that test so misleading as to make it necessary to make our tests exactly like the conditions of actual service. We wound a coil of double cotton-covered wire about a steel rod, saturated the coil with insulating compound, withdrew the steel rod, inserted in its place an ordinary thermometer, put current through the coil via water resistance, until the coil was so badly heated as to give off dense volumes of smoke, and if by weighing we found that a coil did not lose more than 10 per cent. of its compound, we decided that such material would stand hot service in overloaded machines. An insulating compound should have such a high melting point. The designer of a motor never can tell which one of his machines will be located in the hottest corner of a rolling mill, or whether his generator may not some day have to stand the heat of a torpedo boat engine-room with the ventilating apparatus broken down, or an emergency overload in ordinary practice.

The tests to determine the capacity of a given insulating material to exclude moisture from the coils of an idle machine were chiefly a process of elimination, and here we found aid from the experience of varnish and paint manufacturers, and in the researches which have been made concerning the materials which enter into their products.

We first eliminated shellac for the reason that it could only be made into a successful varnish by dissolving it in alcohol, or alcohol and water. You can make a shellac varnish totally devoid of water, but you cannot do it commercially, and if you could you could not keep it so, as the alcohol in shellac varnish rapidly attracts moisture the moment it is exposed or applied.

The copal varnishes and asphalt varnishes were eliminated at this point, as we found that the heat and vibration of magnet coils quickly reduced them to a powder, or cracked their films so badly that they could not exclude water any more than a sieve could hold it.

For some time we thought that linseed oil might be so boiled that it would effectively exclude moisture. We were attracted by its high initial resistance and the extremely tough film which could be obtained from varnishes composed of it; but here again we were stopped by the accumulated facts which experienced varnish and paint makers furnished us.

Linseed oil is a commercial commodity solely because of the rapidity, as compared with all other oils, with which it absorbs oxygen. A method of arresting the oxidation of a film of linseed oil at any desired point would be of immense value to the electrical fraternity. We cannot hope to arrest the oxidation of a film of linseed oil at any particular point. It continues to oxidize until it becomes a brittle, cracked and utterly.defenseless mass so far as its capacity to prevent the passage of any stray electric current is concerned. More electrical apparatus has been reconstructed or repaired because of the oxidation and other defects of linseed oil than of all other causes put together.

A great many electricians like to claim that their apparatus is well ventilated. "Well ventilated" also means well oxidized. There are very few armatures which are not well ozonized also.

When the wearer of a black coat leans against the white trimmings of a house which was painted with linseed oil and white lead last Spring he has to dust himself off, simply because the oil, which should have held the pigment to the house, has been totally destroyed by atmospheric action. It is because of this quality of linseed oil that we are compelled to have a varnishing day in our art galleries, and it has never been disputed that thoroughly oxidized linseed oil is not only soluble in water, but is hydroscopic, since that fact was established many years ago by eminent German authorities.

We had to consider that an insulating compound might be used some day in a generator located on top of a steel penstock in an isolated power-house, where there was no heat, and that when the generator should shut down it would attract moisture at a tremendous rate by condensation. It would not run a week under these conditions if it was insulated with a linseed-oil preparation. It is well known that a series of chemical actions may take place in an electrical machine, wherein linseed oil may be found wholly responsible for the presence of water even before the oxidation of the oil has reached the advanced stage. This occurs when at atom of hydrogen in the oily acids of the varnish is replaced by an atom of copper. The ejected atom of hydrogen selects a pair of friends from the oxide on the wire and thus produces water. It is perhaps needless for me to say that only one material was able to pass these tests for the exclusion of moisture under practical conditions, that being the high-melting-point paraffin compound whose widely successful use has brought to me the honor of delivering this address.

A particular point which led us to the adoption of this material is its capacity to withstand high temperatures for a great length of time and still maintain its original plastic condition. The vibration in a high-speed armature probably equals that in any mechanical device when the shattering jars of gear connections are taken into consideration and when street railway machinery is added to the list of apparatus under consideration.

The expansion of armatures and field coils as they heat, and their subsequent contraction when the loads are removed, are obvious, and consequently any insulation which does not have permanent plasticity under heat is wholly defective for this sort of electrical insulation. Consequently a large list of materials, composed of varnish gums and linseed oil, asphalts, etc., were eliminated one by one as they showed their utter incapacity to stand the shattering influences of this vibratory stress.

The defectiveness of the first material which we ever made was caused wholly by the presence of varnish acid. As is well known to varnish chemists, all of the varnish gums are acid bodies. Indeed, it is safe to say that there is practically nothing in the shape of gum or oil which enters into varnish that is not an acid body.

The question then arose, " How far is anybody warranted in introducing acid into the vitals of high-cost apparatus?"

Of course the answer is, "Just as little as possible;" but I am sorry to say that a good many electricians have declined to give this point the consideration to which it is entitled, and they have thereby become responsible for a great deal of the apparatus which has proven defective.

Of course I am familiar with the claim of some electricians that they "never have any trouble with apparatus built by them." In the first place, we know that such a statement is not true; and if it was true, it would not be a good reason for deliberately disobeying physical law.

From one end of this country to the other you can go in the street-railway field and find apparatus which has gone to the scrap-heap chiefly because it has been insulated with defective insulation. Within a year one of the largest generators in the world has had its armature twice rewound because it was insulated with defective insulation, and on the third trial its builders repaired it with the same stuff which first short-circuited it. The money loss in that instance is already close to $10,000, with more to follow. There is not a central station manager in the United States who has tried to sell power who has not come into contact with a manufacturer or a machine-shop superintendent who told him he would not put in a motor unless the central station man would guarantee against his shut-down losses and against repairs. Printers have discarded electric motors for gas-engines because they say the gas-engines have a reliability which motors have not.

Every defective electric motor is an argument for the sale of an engine in its place, and it is only so because the motor manufacturers have neglected in their rush to keep up with commercial progress to give to their insulation the same care and thought which the engine builders have given to their construction. The same processes of elimination which keeps poor metal out of piston rods will keep poor insulation out of armature coils. But at present manufacturers will not seek such improvement until consulting and operating engineers insist upon it.

The obvious unfitness of linseed oil for motor insulation, because of its acid composition, is best explained by reference to indisputable authority. What everybody knows "is most indisputable authority," and anybody who knows anything about chemistry knows that an acid is a body which will attack metal. An acid is a body which attacks copper. An acid is a body which will combine with copper to produce a third and possibly a fourth material. Users of shellac, copal varnish and linseed-oil varnish as insulation have frequently found that the cotton covering of their wire has been turned a brilliant green, which is a universal symptom that the copper has been attacked by an acid.

When we said that such a symptom was a bad one, some electricians argued with us and said they didn't think we had any authority for that statement, and that it didn't make any difference if a coil did turn green, provided that coil was properly baked out. They declined to accept what every chemist knows.

We have given considerable thought to this matter, and have come to the conclusion that a green coil is an evidence of bad construction, is *prima facie* evidence that a radical chemical change has gone on within precincts whence chemical changes should be excluded with great rigor.

Green discoloration is evidence of inconstancy where constancy is indispensable. As it is very seldom seen except as a relic of a broken-down machine, it may therefore be said to be coincident with burned-out and short-circuited machines; but this discoloration becomes more potent in its suggestiveness as we consider what takes place to produce such a radical physical change—a change visible to the naked eye, a change positive and far-reaching enough to send the green coloring matter through mica $\frac{1}{16}$ of an inch thick and to impregnate thick wrapping-paper and fiber stock. In the study of this action we need accept nothing but the facts and authority which is beyond dispute by being common knowledge. When we see a piece of mica that was once a beautiful amber color turned green, when we find that it would stand a puncture strain of 10,000 volts while amber color and can be punctured with 1,000 volts since its color has been altered, and we find that it has actually failed to prevent the passage of a current of not over 10 volts, we have a right to conclude that there is a relation between such green discoloration and coincident drop in insulation resistance; and we have a right to carry that conclusion a step further and decide that the short-circuit was caused by the chemical transformation of which the color change is evidence.

At least we are justified in a further exploration and examination in the light of the simplest variety of information on a simple chemical action. By so doing we find that it is easy for a varnish to have a chemical effect upon copper. Such action is the rule rather than the exception, and now, by reference to well-known authority, we find that this green action is the characteristic one of acids upon copper. The presence of acids near copper is always evidenced by green discoloration. Vegetable acids substitute atoms of copper for atoms of hydrogen in common with other acids. We are justified in concluding that such substitution of copper for hydrogen takes place in a gaseous or semi-gaseous state. We shall now be able to apply the knowledge that vaporized copper has a high conductivity, and we shall then come to an unassailable conclusion that during the time when that mica was being impregnated with that vapor or varnish-copper the insulation of the mica was so reduced that an easy passage was afforded to the 8- or 10-volt current which effected the short-circuit.

When we find that the green discoloration may take place in an idle machine and not short-circuit it, and that short-circuits always appear when the green discoloration takes place in a machine which has been constantly in operation, we obtain further proof of a positive nature that acids should not be permitted to enter into coil construction under any circumstances—not even when they are loaded with black coloring matter to cover up their corrosive action.

In this connection we exploded one of the Mother Goose melodies or superstitions of the electrical fraternity—the foolish notion that lubricating oil caused short-circuits. Lubricating oil never will, never did, it never can, cause a short-circuit. If we could design a generator which would run in oil, immersed in oil just as transformers are built, we should undoubtedly produce a successful machine. Why then should lubricating oil cause a short-circuit?

The first electrician who had a short-circuited machine was naturally disappointed and wanted an excuse; and when he found that lubricating oil had penetrated into the coils, he accused it of causing the trouble. What actually occurred was this: the lubricating oil came in and stirred up the dormant or satisfied acids of the varnish which he had used. Varnish-makers who have essayed to manufacture insulating compounds have on several occasions claimed that their varnishes were oil-proof. This was nothing but a joke, however, and they never expected anybody to believe it. Varnish salesmen sometimes attempt to prove that an insulating varnish is oil-proof because they can coat a newspaper with it and the newspaper will hold oil in the open air and away from the heat of operating apparatus. As a matter of fact, varnish which is so proved to be oil-proof will unite readily with lubricating oil under a temperature of 150° F.

The trouble is, that it will not unite homogeneously. The oil unites with one part of the varnish and separates that part from the remainder of the varnish, so that there are two or three separate and distinct bodies where there was originally but one. In one or both of these the acids are now unsatisfied and they immediately attack the copper, and, as before described, cause the short-circuits which were attributed to lubricating oil.

The oil was absolutely innocent. It is absolutely indispensable, and the acids of acid insulations are not indispensable.

Inasmuch as it is feasible, by working in the paraffin series, to make non-acid insulating compounds which have complete chemical affinity for lubricating oil, it is perfectly easy to obtain insulation for a machine which will be friends with and welcome all the good insulation which may soak into it from its bearings in the form of oil.

IRON AND STEEL TRADE IN 1902.

The report, now in press, on the iron and steel trade for 1902, by Mr. James M. Swank, United States Geological Survey, shows a continued advance in the annual domestic production of pig iron, the excess over 1901 being 1,942,953 tons, or almost 12·24 per cent. The total production in 1902 was 17,821,307 long tons, as compared with 15,878,354 tons in 1901, 13,789,242 tons in 1900, 13,620,703 tons in 1899, 11,773,934 tons in 1898, and 9,625,680 tons in 1897.

Notwithstanding this increase of production, the imports of iron and steel in various forms amounted in foreign value in 1902 to $41,468,828, as against $20,395,015 in 1901, an increase in 1902 of $21,073,811, or over 100 per cent. The total exports of iron and steel, including locomotives, car wheels, machinery, etc., amounted in 1902 to $97,892,036, as against $102,534,575 in 1901, $129,633,480 in 1900, $105,690,047 in 1899. The exports of agricultural implements, which are not included above, amounted in 1902 to $17,981,497, against $16,714,308 in 1901.

The consumption of pig iron in 1902 was approximately 18,439,899 long tons, of which 625,383 tons were imported, as compared with 16,232,446 tons in 1901, of which 62,930 tons were imported. The increased production of pig iron in 1902 over 1901 was 1,942,953 tons; the increased consumption was 2,207,453 tons.

At the close of 1902 the number of furnaces in blast was 307, as compared with 266 at the close of 1901 and 232 at the close of 1900. At the close of 1902 105 furnaces were out of blast—many being temporarily banked from lack of fuel—as against 140 furnaces at the close of 1901.

The production of Bessemer steel ingots and castings increased more than half a million tons in 1902—to 9,306,471 long tons; the production of Bessemer steel rails remained almost stationary. The production of open-hearth steel ingots and castings in 1902 was 5,687,729 long tons, an increase of 1,031,420 tons over 1901.

In the fiscal year 1902 there were built for mercantile service 106 steel vessels and one iron vessel, with a gross tonnage of 280,362 tons, as compared with 119 steel vessels and one iron vessel, with a gross tonnage of 196,851 tons, built in 1901. Of these 107 vessels, 49, with a gross tonnage of 161,930 tons, were built at ports on the Great Lakes.

The production of pig iron in Canada in 1902 increased to 319,557 long tons, over 30 per cent. as compared with 1901; and the production of steel ingots and castings in 1902 was 182,037 long tons, as compared with 26,084 tons in 1901, an increase of 155,953 tons, or nearly 600 per cent.

The second part of Mr. Swank's report consists of an interesting and valuable series of tables presenting complete statistics of the production of iron and steel, iron ore and coal in the United States, Great Britain, Germany, France and Belgium, to the close of 1901, thus showing the progress that has been made by these countries in the first year of the twentieth century.

PHYSICAL SECTION.

Read by title at the Stated Meeting held May 21, 1903.

On Convergents and Arithmetical Series, the Ratio of Whose Terms Approximate Successively the Value of π; and on Their Application to the Construction of Computing Machines.

By F. L. O. Wadsworth.

Several years ago I had occasion to make use of a complicated reduction formula, the numerical application of which involved the frequent use of a value of π accurate to the sixth decimal place. In order to avoid the continued manipulation of the large number of figures which this necessitated, I substituted for the decimalized value a ratio between two whole numbers, P and Q, so chosen as to express this value to the required degree of accuracy. These numbers are easily found by the method of convergents. For the value of π required, *i. e.*, $\pi = 3{\cdot}1415927$, this gives

		c	⌋
$\frac{P}{Q} \doteq C_1 = \frac{3}{1}$	$= 3{\cdot}0000000$	3	$141592{\cdot}7 \times 10^{-6}$
$\doteq C_2 = \frac{22}{7}$	$= 3{\cdot}1428571$	7	$1264{\cdot}4 \times 10^{-6}$
$\doteq C_3 = \frac{333}{106}$	$= 3{\cdot}1415094$	15	$83{\cdot}3 \times 10^{-6}$
$\doteq C_4 = \frac{355}{113}$	$= 3{\cdot}1415929$	1	${\cdot}2 \times 10^{-6}$
$\doteq C_5 = \frac{126003}{40108}$	$= 3{\cdot}14159269+$	354	${\cdot}01 \times 10^{-6}$
$\doteq C_6 = \frac{252361}{80329}$		2	
$\doteq C_7 = \frac{1640169}{522082}$		6	

	c	Δ
$\doteq C_8 = \frac{1892530}{602411}$	1	
$\doteq C_9 = \frac{9210289}{2931726}$	4	
$\doteq C_{10} = \frac{11102819}{3534137}$	1	
$\doteq C_{11} = \frac{31415927}{10000000} = 3 \cdot 1415927$	2	$0 \cdot 0000 / 10^{-6}$

The terms c and Δ of the above series denote respectively the "components" of the continued ratios and the differences between the successive convergents and the required value. The relations between the quantities C_1, C_2, ... C_n are expressed by the well-known equation

$$C_n = \frac{P_n}{Q_n} = \frac{C_n P_{n-1} + P_{n-2}}{C_n Q_{n-1} + Q_{n-2}} \tag{1}$$

The remarkable characteristics of this particular series of convergents is the very rapid decrease in the value of Δ for the first four terms of the series. The third convergent, C_3, of the series expresses the correct value of π to within one unit in the fourth decimal place, *i. e.*, to within 1 part in about 38,000; the fourth convergent, C_4, expresses the required value to within 2 parts in the *seventh* decimal place, or to within 1 part in about 15,000,000. It is very unusual that an incommensurable number such as π can be expressed with this degree of accuracy by a ratio between two numbers, each consisting of only three figures.

The third convergent, C_3, expresses the value of π to the degree of accuracy usually necessary in computations. For such purposes it is, however, just as easy to employ the fourth convergent, C_4, which is of exactly the same order of magnitude as C_3. The same statement applies to the use of these ratios in computing machines and mechanical solutions of equations involving this constant. In the latter operations, however, we can frequently employ with advantage a ratio which is less accurate and involves fewer numbers than C_3, but which must be more accurate than the next lower convergent, C_2, whose error is about 1 part in about 2,400. This led me to search for other ratios intermediate both in order and accuracy to $C_2 - C_3$, and to the discovery of the arithmetical series which it is the first purpose of this paper to describe.

It will be noted that the "component" or approximate ratio, c_4, of the fourth convergent is unity. From (1) it follows, therefore, at once that

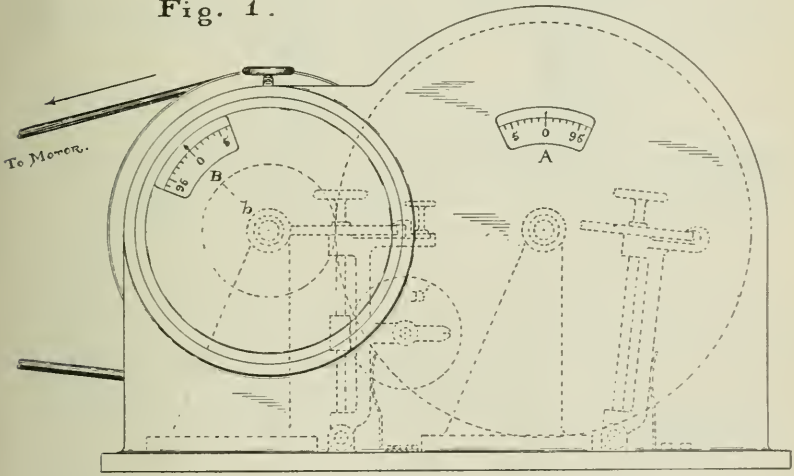
$$P_4 = P_3 + P_2$$

and

$$Q_4 = Q_3 + Q_2$$

That is, both terms of the convergents C_3 and C_4 are members of arithmetical series whose common differences are the corresponding terms, 22 and 7, of the convergent C_2.

Fig. 1.



This suggested to me the probability of the lower terms of the same series forming ratios which would be intermediate in value between the convergents C_3 and C_4 and the convergent C_2. This was found to be the case. The two series are

$$S = 1 + 8 + 15 + 22 + \ . \ . \ 106 + 113 + 120, \text{etc.}$$

$$S' = 3 + 25 + 47 + 69 + \ . \ . \ 333 + 355 + 377, \text{etc.}$$

The successive values of the ratios

$$\frac{S'_m}{S_m}$$

are

$$\begin{array}{llllll}
 & & & & & \Delta_m \\
m = 1 & \dfrac{S'_1}{S_1} = \dfrac{3}{1} & = 3{\cdot}000000 & = C_1 & - & 141592{\cdot}7 \times 10^{-6} \\
m = 2 & \dfrac{S'_2}{S_2} = \dfrac{25}{8} & = 3{\cdot}125000 & & & 16592{\cdot}7 \times 10^{-6} \\
m = 9 & \dfrac{S'_9}{S_9} = \dfrac{179}{57} & = 3{\cdot}1403509 & \doteqdot C_2 & - & 1241{\cdot}8 \times 10^{-6} \\
m = 10 & \dfrac{S'_{10}}{S_{10}} = \dfrac{201}{64} & = 3{\cdot}1406250 & & - & 967{\cdot}7 \times 10^{-6} \\
m = 11 & \dfrac{S'_{11}}{S_{11}} = \dfrac{223}{71} & = 3{\cdot}1408451 & & - & 747{\cdot}6 \times 10^{-6} \\
m = 12 & \dfrac{S'_{12}}{S_{12}} = \dfrac{245}{78} & = 3{\cdot}1410256 & & - & 567{\cdot}1 \times 10^{-6} \\
m = 13 & \dfrac{S'_{13}}{S_{13}} = \dfrac{267}{85} & = 3{\cdot}1411765 & & - & 416{\cdot}3 \times 10^{-6} \\
m = 14 & \dfrac{S'_{14}}{S_{14}} = \dfrac{289}{92} & = 3{\cdot}1413043 & & - & 288{\cdot}4 \times 10^{-6} \\
m = 15 & \dfrac{S'_{15}}{S_{15}} = \dfrac{311}{99} & = 3{\cdot}1414141 & & - & 178{\cdot}6 \times 10^{-6} \\
m = 16 & \dfrac{S'_{16}}{S_{16}} = \dfrac{333}{106} & = 3{\cdot}1415094 & = C_3 & - & 83{\cdot}3 \times 10^{-6} \\
m = 17 & \dfrac{S'_{17}}{S_{17}} = \dfrac{355}{113} & = 3{\cdot}1415929 & = C_4 & + & 0{\cdot}2 \times 10^{-6}
\end{array}$$

The ratio

$$\frac{S'_9}{S_9}$$

is very nearly equal to C_2. Any desired degree of approximation to the value of π between C_2 and C_4 may be secured by choice of a suitable value of m from the above table. Thus, for a degree of approximation of 1 part in 10,000 we select the ratio for which $m = 14$, *i. e.*,

$$\frac{S'_{14}}{S_{14}} = \frac{289}{92}$$

This ratio is sufficiently accurate for all ordinary computations and mechanical solutions, and involves one less figure than either the ratios C_3 or C_4.

GRAPHICAL AND MECHANICAL COMPUTATIONS.

The very accurate representation of the value of π by the simple ratios just found enables us to readily obtain the circumference of any circle whose diameter is given, or, *vice versa*, by means of an ordinary slide rule, or, better still, by a simple gearing. If we gear together two wheels which contain respectively 355 and 113 teeth, the angular motion of the second will be π times that of the first. If we add two dials divided into the same number of parts and two revolution counters to register the whole turns, we can obtain the product of any number of figures by π correct to within two units in the eighth place.

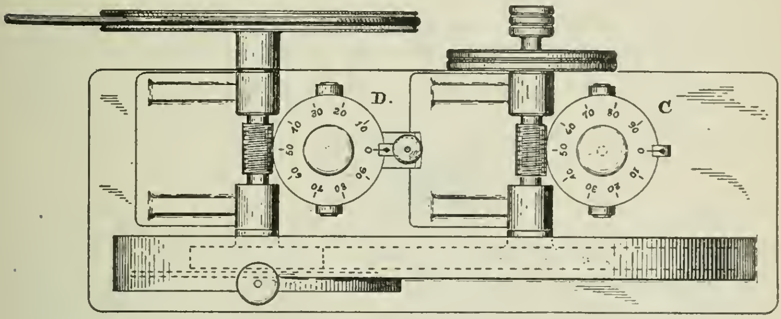


Fig. 2.

A plan and front view of a machine constructed for this purpose is shown in *Figs. 1* and *2*.* The two gear wheels are 48 pitch, and are therefore 7·396″ and 2·354″ pitch diameter respectively. They are provided with dials, each about 4″ in diameter, divided into 500 parts graduated from 0 to 100. The revolution counters are two worm wheels, each having 100 teeth driven by worms on the axes of the two gears. With well-cut gears the error due to irregular spacing, roughness in the teeth, etc., etc., does not exceed 2 per cent. of the tooth space. The accuracy of the ratio between the readings of the two dials can therefore be relied upon to within $\frac{1}{10}$ of a division, *i. e.*, to $\frac{1}{5000}$ of a revolution. If, therefore, we demand an accuracy of 1 part in the seventh decimal place, *i. e.*, $\frac{1}{30000000}$ of the value of π, we must revolve the driving gear A at least 200 times. Thus, if the number x, whose product by π is desired is 10,254, $10\frac{254}{1000}$ turns of the dial and gear A will give the product πx on the dials of gear B to 1 part in 50,000; $102\frac{54}{100}$ turns of A will give the product πx to 1 part in 500,000; and $1{,}025\frac{4}{10}$ turns, the product πx to 1 part in 5,000,000. Similarly, if the number x is 495687·3, we must give A $495\frac{6873}{10000}$ turns if we wish to obtain πx to the same number of significant figures. For operations involving this number of figures it is inconvenient to turn the wheels by hand, and a small motor belted to the axis of B, as shown by the dotted lines, is provided for this purpose. The motor is, of course, stopped just before the final reading is reached and the operation completed by hand. In order to return the readings to zero for another operation, the worms C and D may be lifted out of engagement with their respective axes, as shown by the dotted lines of *Fig. 1*, and the index mark of wheel B adjusted and clamped at any point on the circumference of its respective dial. The index mark of D is correspondingly adjustable over a space of 1 division, so that there may never be any uncertainty as to the whole number of revolutions indicated by D.

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* I have been unable to find the original drawings, and as the machine itself is not now in my possession, the general details of the device are drawn from memory and may not exactly correspond to those of the original construction. They are, however, essentially the same.—AUTHOR.

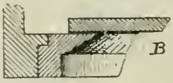

Fig. 3.

With this machine it is possible to obtain the product of any given number of 8 places or less by π much more easily and quickly than it can be done by the use of logarithms or by any of the usual forms of calculating machines.

For less accurate work a much smaller instrument can be constructed by using the ratio S_{14}, making the gears of finer diametrical pitch and omitting the revolution counters *C* and *D*. Greater compactness can also be secured by using, instead of external gears, two concentric internal and external gears of 289 and 92 teeth respectively, connected by idler gears. The reading dials can be placed on opposite sides of the small circular case containing the whole. In this way, using gears of 128 pitch, an instrument of about 2½ inches diameter and ½ inch thick, or about the size of an old-fashioned watch, can be made. This is small enough to be readily carried in the pocket and will enable a machinist to mechanically rectify, or, if desired, "square" a circle of any given diameter with an accuracy of 1 part in 10,000.

ALLEGHENY OBSERVATORY, April, 1903.

POWER-TRANSMISSION POSSIBILITIES IN THE SOUTHERN APPALACHIANS.

The present commercial possibilities in the electrical transmission of power over long distances with small loss, and the opportunities thus offered for the combination of a number of small plants into one of considerable magnitude, serve to direct attention to a number of water powers in the Southern States which are now totally ignored.

The popular idea of an available water-power is a moderate fall on a stream of considerable size, located within a few yards of a railroad. Like many popular ideas, it is only partly correct. The power which can be obtained at any power site on a stream is the product of the weight of the water passing the site per unit of time multiplied by the height of the perpendicular fall obtainable, and for the same total power these quantities vary inversely; that is, if the head be doubled, the quantity of water may be diminished by a half and the resultant power will be the same; if the head be multiplied by ten, then one-tenth the quantity of water will yield the power, and so on, in similar ratio.

Given a sufficient fall, therefore, a small amount of water may be made to furnish a very large amount of power, and, in point of fact, many of the large power developments of the Western States are of this type, the quantity of water used being small, but the head being measured by hundreds of feet. The distance between the points where the power is developed and where it is to be utilized is annihilated by electrical transmission.

A large number of streams in that part of the Southern States in which the Appalachian Mountain system attains its maximum development have their sources far up on the mountain slopes, in regions of great rainfall and of large and permanent run-off, and these, in their courses to the valleys below, often fall hundreds of feet within short distances. By the application of proper methods these streams are capable of furnishing and transmitting power in considerable quantity at comparatively small cost, certainly in many instances at less cost per unit of power obtained than would be possible on the large trunk streams, and without the attendant risks.

The flow of many of these streams, now unused and indeed ignored, has been measured by the engineers of the United States Geological Survey, and the results have been published in the series of Water-Supply and Irrigation Papers.

LIFE OF ENGLISH LOCOMOTIVES.

An English lecturer recently stated the average life of an English express locomotive to be 25 years; of a local passenger engine, 25 years; of a freight locomotive, 26 years, and of a switching engine, 27 years. The total mileage of an express passenger engine was placed at from 700,000 to 1,000,000 miles; and for each of the other classes of engine a mileage of 500,000 to 800,000 was given. In the United States, the average life of an express locomotive was given as 18 years; of a local passenger engine, 19 years; of a freight engine, 16 years, and of a switch engine, 22 years. Whereas the mileage of an English express locomotive was only at the outside 1,000,000 miles in 25 years, or 40,000 per year; in the United States it is often as high as 2,000,000 miles, or 110,000 miles per year.—*Iron Age.*

PROFESSOR BELL'S KITE EXPERIMENTS.

The final paper read before the last meeting of the Academy of Sciences was "On the Tetrahedral Principle in Kite Structure," by Alexander Graham Bell. At the outset he said that in the old Hargrave box kite, and all subsequent kites and flying machines of the same order, there were two important defects, which he described as follows: The box kite is braced in a horizontal and vertical direction, but not otherwise, so that cross supports have to be introduced in the frame, which increase the weight without adding to the flying power, and at the same time operate as an obstacle to the wind. The chief defect of the box kite, of which Dr. Langley's aerodrome is an elaboration, is that the weight increases with the cube as rapidly as the lifting power does with the square, so that the larger the kite, the less it will lift in proportion. In view of these facts, he had been led, he said, to construct a kite, the frame of which would present the form of a triangle no matter from what side one viewed it. In other words, the frame was a perfect tetrahedron; and in experimenting with the same, he found, as he had expected, that it was self-braced in every direction, and moreover, that the lifting power increased at a greater ratio than the increase in weight. He was, furthermore, surprised at the facility with which such a kite could be managed. By combining a great number of these kite tetrahedrons he had recently built up an immense kite, with which he successfully lifted not only a man, but a weight of 200 pounds, showing the vast improvement of this over all previous machines of the same order.

Mechanical and Engineering Section.

Stated Meeting, held April 16, 1903.

Fuel Oil.

By John F. Rowland, Jr.

Under the conditions of using a triple expansion engine, a horse-power hour may be obtained for a pound and a-half of coal per hour, and if the boilers, engine and condenser be properly looked after, this result is continuously possible, using the average grade of either anthracite or bituminous coal.

It may be either from the impossibility of using steam in this multiple expansion manner because of the smallness of the unit, or the undesirability on account of the difficulty or expense of obtaining condensing water, that power is had from the expansion of steam in a single cylinder without a condenser.

The endeavor to obtain from this latter condition the best possible economy has resulted in the numerous devices for supplying coal to a boiler in a mechanical manner, both in the natural and pulverized forms.

There has been supplied in the same natural manner another form of combustible than coal, which is the subject of this evening's discussion, viz., oil.

For many years refined oils have been used as fuel where the greater heat value alone determined the selection, but its use in large quantities where it has replaced coal is confined to such as is found in the natural state.

There are about 19,000 heat units in a pound of oil, and about 12,000 available ones in a pound of coal.

In comparing the two fuels, it is not alone the difference in heat value per pound that must be considered.

There are objections to the use of coal which would make oil the more desirable fuel if the heat values were the same, provided the cost of oil allowed the selection.

In the ordinary way of firing coal there is the opening and shutting of the fire door with the constant change of temperature and the effect of this change upon the furnace, the combustion chamber and tubes in an internally fired boiler, and upon the shell or tubes in an externally fired one.

It is from the effect of this change that most of the deterioration in boilers is due, and most of the expense of upkeep is entailed.

The deposition of soot on the tubes of a boiler constitutes perhaps the greatest heat waste in burning coal, and coal can hardly be burned in a manner to prevent this. Until the ashes from the burning of coal are removed from the vicinity of a boiler, there is a constant deterioration of any metal with which they come in contact.

It is possible, in burning oil, to dispense entirely with the temperature changes, there are no ashes to remove, and careful burning of the oil leaves very little unburned carbon.

The burning of oil entails a minimum of expense for operating.

The oil may be burned with the use of either steam or air, or a combination of the two, to atomize it and to provide sufficient oxygen for combustion.

In selecting an oil burner that uses steam to atomize the oil, care must be taken that the quantity of steam be not too great a percentage of the total amount generated.

If the plant where oil is burned uses pneumatic tools, it may be more advantageous to use air.

Where a forced draft system of combustion is used, a combination of steam for atomizing and air for combustion may be used, and this combination gives results that have probably not been exceeded for economy.

In a plant of over 4,000 horse-power, using steam to atomize the oil and air at a pressure of 3 inches of water for combustion, there is obtained regularly a net evaporation of 14·1 pounds of water from and at 212° per pound of oil. The tubes are sponged in this plant once a month, as against every day when coal was used, and no repairs to furnaces or tubes have been necessary after seven months.

There is a considerable difference in the price of oil, depending on the distance it has to be carried, and while the price may be prohibitive where the distance is great, the fact remains that oil is largely superseding coal as a fuel, and when the economy of operation where oil is used has been continued for a sufficiently long time to have the results studied and diffused, there is no question but that oil will be still more generally used as a fuel.

ELECTRICITY ON THE ELEVATED RAILWAYS OF NEW YORK.

The substitution of electricity for steam upon the elevated railways of New York has proved a great success, not only in the direction of economy but in accelerating the speed, which on a railway of the kind in question is a matter of the greatest importance. The *Scientific American* asserts that the electrical horse-power employed amounts to 45,000, which is far above the average steam-power in use formerly. The average speed is not only increased, but more cars can be hauled by 25 per cent. and the average number of passengers carried daily is 800,000. The greatest tractive effort exerted upon a train is now 20,000 pounds, where the motors are distributed throughout the train, each car being available for adhesion; but when locomotives were employed the utmost traction on the draw bar was only 7,000 pounds. The service has been so improved that the time between terminals has been reduced 25 per cent., so that with the same headway it is possible to run 25 per cent. more trains than with the steam service. In the matter of cleaner service, absence of noise, abolishment of dripping oil and hot water, there is no comparison between the steam and the electric systems.

ARTIFICIAL GRAPHITE.

The manufacture of artificial graphite has assumed a very prominent position in the graphite industry in recent years, the production in 1902 amounting to 2,358,828 pounds, as compared with 2,500,000 in 1901 and 860,750 pounds in 1900. The production of both the crystalline and amorphous variety has been steadily developed by the sole producers, the International Acheson Graphite Company, at Niagara Falls, N. Y., who began their operations in 1897 with a product of 162,382 pounds. The decrease in unit value of the total production from 8 cents per pound in 1899 and 1900 to 4·75 cents per pound in 1901 and 4·69 cents per pound in 1902 was largely due to the increased proportion of the amorphous variety produced. The output of 1902 consisted of 885,591 pounds of graphitized electrodes and 1,475,237 pounds of artificial graphite in the granular or powdered form. The electrodes were used in electrolytic processes for the production of caustic soda and of chlorine and metals in chloride solution; also in electro-metallurgical processes, such as the production of calcium carbide, the electric smelting of copper and iron ores and the manufacture of various iron alloys. The artificial graphite in the form of grains and powders was used chiefly in the manufacture of paint, dry batteries and commutator brushes, although a considerable quantity was used in the manufacture of lubricants, in electroplating work, and in certain chemical processes requiring a carbon of exceptional purity.—*Iron Age.*

MACARONI WHEAT.

The success of macaroni wheat in this country is a matter of great importance to grain growers. It has been demonstrated that not only is the yield greater than common wheat, but it brings a much higher price and thrives in localities where ordinary wheat fails or gives but a scant yield. In South Dakota, where the experiments were carried on, from 60 to 120 per cent. more macaroni wheat was grown than that given by the blue stem or Fife wheat, and where 150,000 acres were sown with it last year, 300,000 are under cultivation this year. Last year was an unfavorable one for this variety, much of the crop being injured by rain and sleet. In spite of this the yield was 80 per cent. greater than the regular crop. Macaroni mills abound in Minnesota, Dakota, Pennsylvania, and New York. To keep them going, thousands of bushels of macaroni wheat were imported; even with this they were compelled to use bread wheat to some extent, which results in a lower grade of goods. This high-grade wheat makes far better and more palatable bread than that generally used, so it will be in demand for that class of work. It is stated by Professor Carleton, the macaroni expert in this country, that the wheat crop can be increased 50,000,000 bushels readily by more attention to the subject.—*Iron Age.*

LARGEST BLOWN GLASS BOTTLES.

On May 9th the largest glass bottles ever blown were made at the plant of the Illinois Glass Company for exhibition at the World's Fair. The capacity of each bottle is 45 gallons. It was not until after many unsuccessful attempts that the bottles were made. Four perfect bottles were produced. Each stands near 6 feet high and measures about 16 inches across the bottom. The men who blew the bottles each supplied about 11,000 cubic inches of air. —*Iron Age.*

SALAMANDERITE—A NEW PRODUCT FROM ASBESTOS.

One of the latest of the asbestos discoveries has received the name of "Salamanderite." Besides being thoroughly fire-proof, it can be made to duplicate any decorative effect obtainable by the finest cabinet work in the costliest woods, or by tiling, and at a small percentage of the cost of the genuine article. It may be finished in exact fac-simile of quartered oak, mahogany, maple or any fancy cabinet woods, either plain or in the finest marquetry or bas-relief effects, indistinguishable from the most costly work, so says a recent prospectus. Its value for churches, theatres, steamships, residences and other structures is obvious.—*Iron Age.*

CHEMICAL SECTION.

Stated Meeting, held January 29, 1903.

The Census of Manufactures of 1900.

BY CHARLES E. MUNROE.

(*Concluded from p. 48.*)

Wherever the card catalogue revealed the failure or neglect of an enumerator or special agent to secure a return for an existing establishment, the attempt was made to obtain it by correspondence, often successfully. In the case of some very large establishments thus overlooked, it was necessary to send a special agent directly to the establishment in order to secure a return. In many instances the failure to secure a return on the first canvass was due to the fact that the manufacturing establishment was located beyond the city limits and fell, therefore, within the jurisdiction of enumerators who neglected it. The growing tendency of manufacturing establishments to locate at points convenient to a great city, but outside its corporate limits, increases the difficulties of a thorough canvass of manufactures, which can be fully overcome only by the use of the card catalogue just described. Another difficulty arose from the tendency to render the factory report from the city office as if the operations were carried on at the office. Thus in my own topic returns received made it appear that an industry which produces much dirt was being conducted in one of our most sumptuous office buildings and that many fertilizer factories were located on high-priced property in one of the busiest thoroughfares. The incongruity of these returns led to an investigation, which revealed the fact that not only were the factories not located at the places given, but that in some instances they were not even in the city or the State returned, but in an adjacent State. Such errors were not uncommon in the first returns, but they were serious and had to be corrected; for, as legislation upon public and local interests for a considerable term of years will be guided largely by the statistics of this census, it was essential to make the returns as exact as possible, particularly as regards location.

In drafting the schedules a general schedule embodying the interrogatories required by the Act and common to all industries was prepared. This general schedule was an improvement over the similar schedule used at the previous census, in that it was printed upon four pages instead of eight, and contained detailed instructions as to the manner in which the answer to each question should be enacted. Any enumerator, special agent or manufacturer, at all in doubt as to the nature of the information desired in response to each question, had merely to turn to the last page for his instructions. The special schedules contained the same interrogatories as the general schedule, but with certain of them in a more expanded form and with greater detail as prepared by the expert special agents to fit the particular selected industry that the agent was detailed to treat of.

The general schedule called for:

[Page 1.]

7—469.

TWELFTH CENSUS OF THE UNITED STATES.

SCHEDULE No. 3.—MANUFACTURES.

State . . . . Supervisor's District No. . . . . .

County . . . . Enumeration District No. . . . .

Collected by me on the . . . . . day of . . . . , 1900.

. . . . *Special Agent or Enumerator.*

Name of establishment . . . .

Name of corporation, firm, or individual owner . . . .

Location of factory or shop: { City or town . . . .
{ Street and No. . . . .

Post Office . . . .

(Manufacturing establishments operated by the same corporation, firm, or individual, and located in different towns or cities, must be separately reported.)

DEPARTMENT OF THE INTERIOR.

CENSUS OFFICE.

Washington, D. C., June 1, 1900.

The information returned on this schedule should cover the business year of the establishment most nearly conforming to and preceding the census year, which ends June 1, 1900.

All answers will be held absolutely confidential. No publication will be made in the census reports disclosing the names or operations of individual establishments in any particular. Special agents and enumerators of the census are liable to a penalty of $500 if they disclose any information obtained in their official capacity.

WILLIAM R. MERRIAM,
Director of the Census.

Extract from Act of Congress, March 3, 1899:

SECTION 22.—* * * "And every president, treasurer, secretary, director, agent, or other officer of every corporation, and every establishment of productive industry, whether conducted as a corporate body, limited liability company, or by private individuals, from which answers to any of the schedules, inquiries, or statistical interrogatories provided for by this Act are herein required, who shall, if thereto requested by the director, supervisor, enumerator, or special agent, willfully neglect or refuse to give true and complete answers to any inquiries authorized by this Act, or shall willfully give false information, shall be guilty of a misdemeanor, and upon conviction thereof shall be fined not exceeding ten thousand dollars, to which may be added imprisonment for a period not exceeding one year."

CERTIFICATE.

This is to certify that the information contained in this schedule is complete and correct to the best of my knowledge and belief.

. . . .

(Signature of the person furnishing the information.)

[Page 2.]

CAREFULLY READ AND FOLLOW INSTRUCTIONS ON PAGE 4.

(1) Date when this establishment commenced operations . . . .
Date when present management commenced operations . . . .

(2) Character of organization, whether individual, corporation, or other form (see instruction 2).

. . . .

(3) Character of industry, kind of goods made or work done (see instruction 3).

. . . .

. . . .

(4) Capital invested—owned and borrowed (see instruction 4).

Land . . . . $. . . . . . .
Buildings . . . .
Machinery, tools and implements . . . .
Cash on hand, bills receivable, unsettled ledger accounts, raw materials, stock in process of manufacture, finished products on hand and other sundries . . . .

Total capital . . . . $. . . . .

---

(5) Persons employed (see instruction 5).

CLASSES.	Greatest number employed at any one time during the year.	Least number employed at any one time during the year.	Total amount paid in wages or salaries during the year.
Proprietors and firm members:			
Men			$
Women			
Salaried officers of corporation			
General superintendents, managers, clerks and salesmen:			
Men			
Women			
All other employees, including pieceworkers:			
Men, 16 years and over			
Women, 16 years and over			
Children, under 16 years			
Total			

AVERAGE NUMBER EMPLOYED DURING EACH MONTH.

(Wage-earners only, including pieceworkers. Do not include proprietors, firm members, officers, superintendents, managers, clerks or salesmen.)

MONTH.	Men 16 years and over.	Women 16 years and over.	Children under 16 years.	MONTH.	Men 16 years and over.	Women 16 years and over.	Children under 16 years.
January				July			
February				August			
March				September			
April				October			
May				November			
June				December			

(6) Months in operation:

On full time . . . . . . ; on three-fourths time . . . . . . ; on half time . . . . . .
on one-fourth time . . . . ; idle . . . .

[Page 3.]

(7) Materials used (see instruction 7).

KINDS.	Unit of Measure.	Quantities.	Cost, not Including Freight.
Purchased in raw state—			
. . . .	. . . . . .	. . . . . .	$ . . . .
. . . .	. . . . . .	. . . . . .	. . . .
. . . .	. . . . . .	. . . . . .	. . . .
. . . .	. . . . . .	. . . . . .	. . . .
. . . .	. . . . . .	. . . . . .	. . . .
Purchased in partially manufactured form			
. . . .	. . . . . .	. . . . . .	. . . .
. . . .	. . . . . .	. . . . . .	. . . .
. . . .	. . . . . .	. . . . . .	. . . .
. . . .	. . . . . .	. . . . . .	. . . .
Fuel	. . . . . .	. . . . . .	. . . .
Mill supplies	. . . . . .	. . . . . .	. . . .
All other materials	. . . . . .	. . . . . .	. . . .
Total cost of all materials	. . . . . .	. . . . . .	. . . .
Amount of freight, if any, paid on the above . . .	. . . . . .	. . . . . .	. . . .

(8) Miscellaneous expenses (see instruction 8).

ITEMS.	Amounts.
Amount paid for rent of works, if any	$ . . . .
Amount paid for rent of power and heat	. . . .
Amount paid for taxes, not including internal revenue	. . . .
Amount paid for rent of offices and for interest, insurance, internal revenue tax and stamps, ordinary repairs of buildings and machinery, advertising and all other sundries not reported under the head of materials	. . . .
Total miscellaneous expenses	. . . .
Amount paid, if any, for contract work	. . . .

(9) Goods manufactured (see instruction 9).

KINDS.	Unit of Measure.	Quantities.	Value or Price at Shop or Factory.
			$
All other products			
Amount received for custom work and repairing			
Total value of all products			
Value of manufactured products for *preceding* business year			

[Page 4.]

(10) Power.

a. Power owned—

CLASS.	Number.	Horse-power.
Engines: Steam		
Gas and gasoline		
Water wheels		
Electric motors		
Other power (specify kind)		

(*b*) Power supplied to other establishments, if any—
Horse-power . . . .

(*c*) Power supplied by other establishments, if any—
Kind of power . . . . ; horse-power . . . .
Name and address of establishment supplying same . . . .

INSTRUCTIONS.

All entries must be made clearly and neatly in ink. Amounts and values must be obtained from book accounts, if such accounts are available. Each question is to be answered. If any question is found not applicable and no amounts are reported, write the word "None."

Give, on page 1, the name, location, street and number, and post-office address of the establishment, and obtain the signature of the person furnishing the information. If the post-office address of the business office is at a different place from that of the plant, give both.

If a mercantile, mining, quarrying, or other business is carried on in connection with manufacturing, the capital, employees, wages, expenses, products, etc., reported must pertain only to the manufacturing.

INQUIRY 2.—*Character of Organization:* State whether the business is conducted by an individual, firm, limited partnership, co-operative association, incorporated company, or in some other form.

INQUIRY 3.—*Character of Industry:* Describe specifically the character of the industry and the kinds of goods manufactured or work done, as, for example, cut nails, chairs, leather belting, brooms, baskets, men's clothing, carpentering, blacksmithing, boot and shoemaking and repairing. Obtain and return with the schedule a card or other printed matter that describes the business.

INQUIRY 4.—*Capital Invested:* The answer must show the total amount of capital, both owned and borrowed. All the items of fixed and live capital may be taken at the amounts carried on the books. If land or buildings are rented, that fact should be stated and no value given. If buildings are both owned and rented, the fact should be stated, and only the value of the owned property given. The value of all items of live capital, cash on hand, bills receivable, unsettled ledger accounts, value of raw materials on hand, materials in process of manufacture, and finished products on hand, etc., should be given as of the last day of the business year reported.

INQUIRY 5.—*Persons Employed:* Account for all persons engaged in the business, both in the management and in production. Give the total salaries and wages paid, which should include board or rent furnished as part compensation. Give the number of proprietors and firm members, and, if they are not paid salaries, so state on the schedule. Stockholders of corporations are not to be reported unless they are salaried officials. Amounts paid for outside contract work must not be included in the wages, but be reported in answer to Inquiry 8.

INQUIRY 6.—*Months in Operation:* The entire twelve months of the year should be accounted for, as, for example, twelve months on full time; or eight months on full time and four months on half-time; or ten months on full time and two months idle.

INQUIRY 7.—*Materials Used:* The actual cost of all materials used during the year must be reported. Give the cost, exclusive of freight charges, and then the total freight paid. If this is not practicable, give the cost including the freight charges, and state that such charges are included. Name the principal materials and give the cost of each. Quantities should be given when possible, and the unit of measurement stated, as "pounds," "tons," "bushels," "feet," "yards," etc. Under the head "Purchased in raw state" give the name and the cost of such articles as raw cotton, iron ore, clay, or other materials that have had no manufacturing forces expended upon them, which enter the factory in a crude state. Under the head "Partially manufactured" give the name and the cost of all partially manufactured articles that have passed through one or more stages of production, such as bar iron, steel, leather, partially dressed stone, lumber, cloth, partially constructed furniture, etc. Opposite "Mill supplies" give the cost of oil, waste and other supplies consumed in the running of machinery.

INQUIRY 8.—*Miscellaneous Expenses:* All items of expense incident to the business not accounted for under Inquiries 5 and 7 must be reported here. Do not include commissions or expenses of sales department or any portion of the freight reported under Inquiry 7 as paid on materials.

INQUIRY 9.—*Goods Manufactured:* Give the value or price charged at shop or factory, not including commissions, or expenses of sales department, and account for all products, including by-products. *The principal products must be enumerated and separate values given for each.* Quantities should be given when possible, and the unit of measurement stated, as "pounds," "tons," "bushels," "feet," "yards," etc. If there are products other than those for which a separate value can be given, their total value should be reported opposite "All other products." The amount received for odd jobs or work done must be given as "Custom work and repairing."

Immediately on receipt of the filled and returned schedules they were examined to see if all of the questions asked had been answered and in the proper form. Next, the returns were analyzed to ascertain if they contained duplications in the entries of money or material; then costs of material and labor were inspected and checked by information obtained from a large number of reliable sources having due regard to the industry under consideration and the locality where the operations were carried on. Then the materials and products were compared as to kind and amount, to ascertain if any inconsistency existed, and these were checked by reliable data at hand. In the industry with which I was charged, the methods of stochiometry were employed to ascertain theoretical yields and then the proper margin for losses in yields was applied and these compared with data from other sources. The returns of capital, miscellaneous expenses, months in operation, employees and wages were investigated by previously agreed upon methods which were issued as instructions by the office to all in any way connected with the examination of schedules.

When errors were discovered, the attention of the special agent who "took" the schedule, or of the person who furnished the information, was called to the matter by correspondence, the particular errors and their character being pointed out. We were aided in making this explanation by the fact that two copies of the schedule were given to each establishment to be filled, one of which was to be retained by the person giving the information and the other forwarded to this office, and by these means a large number of the schedules were perfected. Where this was not done, and the matter was of sufficient importance, a personal visit would be made to the establishment or several establishments of that class, where operations could be studied at close range and the persons conducting the business conferred with directly. This I found to be a most satisfactory method of procedure, for I received the most courteous treatment, was given every facility for procuring information and received the assurance of the manufacturers, when they definitely understood what it was sought to accomplish, that the project met with their complete approval, and, if accomplished, would be greatly to their benefit. When, however, these means of directly securing information were exhausted without avail, then indirect sources were drawn upon. In my own experience I can recall but one instance where the responsible official of an enterprise of magnitude persistently (and it must be said intemperately) refused to give the information required. Yet his obstinacy availed him nothing, as his broader-minded associates in the enterprise took a different view of the matter.

The investigation of the schedules for the chemical and allied industries was especially difficult, because of the large number of instances in which material produced in an establishment was used in further manufacturing operations in the same establishment, and to the further fact that in many cases part of the material consumed appeared as a by-product which was regained and reused in subsequent operations. The separation of this material was essential, not only to prevent duplication, but, also, to present the true condition of collateral manufactures. Thus, in the fertilizer manufacture some manufacturers purchase the sulphuric acid with which to make their superphosphate, while others have sulphuric acid plants in which they make the sulphuric acid which they subsequently consume. In the manufacture of explosives the same conditions hold true for nitric acid, while here also the sulphuric acid is regained and used over. Evidently, to present a true statement of the condition of either of these acid industries these data must be analyzed and separated.

These were some of the perplexities attending the work, but the most unsatisfactory item of all to deal with was capital. In relation to this matter Superintendent Walker said, in the census report of 1870: "The census returns of capital invested in manufactures are entirely untrustworthy and delusive. The inquiry is one of which it is not too much to say that it ought never to be embraced in the schedule of the census, not merely for the reason that the results are, and must remain, wholly worthless, the inquiry occupying upon the schedules the place of some technical question which might be made to yield information of great value, but also because the inquiry in respect to capital creates more prejudice and arouses more opposition to the progress of the enumeration than all the other inquiries of the manufacturing schedules united. It is, in fact, the one question which manufacturers resent as needlessly obtrusive, while at the same time it is perhaps the one question in respect to their business which manufacturers, certainly the majority of them, could not answer to their own satisfaction, even if disposed. No man in business knows what he is worth—far less can he say what portion of his estate is to be treated as capital. With respect, indeed, to corporations having a determinate capital stock, the difficulty of making a correct return in this particular becomes very much reduced; yet, even here, the difference caused by returning such capital stock at its normal value on the one hand, or at its actual selling price on the other, whether above or below par, might easily make a difference of 50 or 75 per cent. in the aggregate amount of capital stated for any branch of industry.

"Where, however, business is carried on outside of incorporated companies the difficulty of obtaining even an approximate return of the inquiry itself, irrespective of the reluctance of manufacturers, becomes such as to render success hopeless. So numerous are the constructions possible, and even reasonable, in respect to what constitutes manufacturing capital, that any thing like harmony or consistency of treatment is not to be expected by a large body of officials pursuing their work independent of each other. The superintendent is free to confess that he would be puzzled to furnish a definition (fit for use by practical enumerators) of manufacturing capital, or even in a single case, with complete access to the books of a manufacturing establishment conducted by two or more partners, and with the frankest exhibit of assets, both of the firm and of the individual members thereof, to make up a statement of the capital of the concern in respect to which he would feel any assurance. When to such difficulty in the nature of the subject is added the reluctance of manufacturers to answer an inquiry of this character, it may be fairly assured, in advance of any enumerations, that the results will be of the slightest possible value."

This opinion has been voiced by many competent persons on many occasions, but the information is still required by law.

Taking the manufacturing schedules as a whole, the quantity of obviously erroneous information received on the first returns was appalling. Many of the schedules showed an obvious misapprehension of the significance of the questions asked; some of the schedules revealed upon their face the intention to mislead and deceive the Census Office. In my personal experience these usually emanated from unwise subordinates, who thought thus to protect the interests with which they were charged. On bringing these returns to the attention of the principals, they expressed regret, tendered apologies, supplied schedules perfected in every detail and rendered every possible assistance. In fact, as stated, after manufacturers became convinced that we were handling the matter intelligently and bid fair to obtain results that would be of value without jeopardizing personal interests, they gave us the fullest assistance. Several furnished a transcript of the statement of their business for the prior six months or year. Others drew from their books a detailed statement of every kind of material purchased by them during the census year, with quantities and costs. Others supplied wage lists; others, precise information as to processes.

In the study of processes and products use was made for the first time in census work of the rich store of information accumulated in our patent archives, and a résumé of the U. S. patents is appended to the report on chemicals and allied products.

During the revision of the schedules Dr. Chatard, my associate, and I perfected a system for carding the returns on the schedules for chemical manufactures, which enabled us to promptly release the perfected schedules for the use of the tabulation division, while retaining the data for the analysis preliminary to the preparation of the report. By this means an additional check was put upon the tabulations, and the scheme had the additional merit that it compelled the closest scrutiny of the returns and thereby prevented items from being overlooked that might otherwise have escaped attention.

There was printed for the Division of Manufactures, 1,250,000 general schedules and 1,037,500 special schedules, or 2,287,500 in all. There were received and examined over 771,000 schedules, and of these 530,470 general schedules and 113,588 special schedules were perfected and tabulated. The publication of the results of the year ending June 1, 1900, began in a preliminary way in March, 1901, with a set of bulletins of which 105 were issued, and the final report was completed and published June 1, 1902, within the time limit set by law. The time required by previous censuses to accomplish this result is shown in the following table:

TIME INTERVENING BETWEEN COLLECTION AND PUBLICATION OF STATISTICS OF MANUFACTURES.

Date of census.	Date when final report was printed.
1850	1859
1860	1865
1870	1872
1880	1883–1888
1890	1895
1900	1902

The report of the census of manufactures for 1900 is published in four quarto volumes, containing 4,237 pages, 1,796 tables, and 114 maps, charts and illustrations. These volumes are numbered 7 to 10 of the reports of the twelfth U. S. census. Volume 7, or Part I of the report, is devoted to a discussion of the plan, method and scope of the twelfth census of manufactures, summary and analysis of results, urban manufactures, power employed in manufactures, description of general tables and statistics for the United States by industries. There is also included here copies of all the schedules used, a record of the cities and towns canvassed by special agents, the instructions to these agents, the instructions for editing the schedules of manufactures and the classification of the industries which was adopted.

Volume 8, or Part II of manufactures, is devoted to separate reports on each State and Territory. The collaboration of expert local authorities was secured in the preparation of these reports, and they are therefore not only filled with statistical data of immediate local interest, but they are replete with historical information, which must be ever invaluable to those who study our industrial development.

Volumes 9 and 10, Parts III and IV, are given up to the special reports on selected industries. The industries selected for treatment are: Combined textiles; cotton, wool and silk manufactures; flax, hemp and jute products; dyeing and finishing textiles; the manufacture of clothing; collars and cuffs; buttons; cotton ginning; flouring and grist-mill products; slaughtering and meat packing; cheese, butter and condensed milk as produced in factories; canning and preserving; oleomargarine; salt; beet sugar; rice; starch; cottonseed products; alcoholic liquors; manufactures of tobacco; manufactured ice; leather; boots and shoes; rubber boots and shoes; leather gloves and mittens; the lumber industry; clay products; glass; turpentine and rosin; paper and pulp; printing and publishing; iron and steel; tin and terne plate; electrical apparatus and supplies; shipbuilding; locomotives; cars; carriages and wagons; bicycles; agricultural implements; metal-working machinery; motive-power appliances; sewing-machines; needles and pins; typewriters; musical instruments; watches and watch cases; pens and pencils; chemicals and allied products; petroleum refining; coke; gas; the utilization of wastes and by-products; and patents in relation to manufacture. In the preparation of this paper I have drawn freely on these volumes with which to supplement my knowledge of the work as gained in a part of the field. This enormous undertaking was accomplished in 1,100 working-days with a force of 412 clerks, most of whom were previously untrained in census methods, at a cost of $1,211,952.87.

From the results it appears that the aggregate value of the products of all manufacturing industries for the census of 1900 is $13,004,400,143. A comparison of this result with that of previous censuses is given in the following table:

AGGREGATE VALUE OF MANUFACTURES.

1810	$198,613,471
1850	1,019,106,616
1860	1,885,861,676
1870	4,232,325,442*
1880	5,369,579,191
1890	9,372,437,283
1900	13,004,400,143

---

* Based on paper currency.

First in rank among the separate industries is iron and steel, with $803,968,273 of gross products; second is slaughtering and meat packing, with $790,252,586 of gross products. Foundry and machine-shop products, lumber and timber products, flouring and grist-mill products follow in close order, each having above $500,000,000 of gross products.

First in rank among the great cognate groups of industries is food and kindred products, with an output of gross products of $2,277,702,010; second is iron and steel and their products, with gross products amounting to $1,793,490,908. Following these are textiles, lumber and its manufactures, and leather and its finished products, forming the first five of the great groups. We might continue to draw from this enormous collection of statistics information going to show the wonderful condition of industrial activity to which this country has attained; a condition which justifies its pre-eminent position as a world-power.

Although the general scope of the manufacturing census of 1900 was limited by law to an exact parallel of the census of 1890, so far as the schedule was concerned, it has, nevertheless, been possible to introduce several important modifications in the presentation of the statistics, which mark a distinct advance in this branch of the census work. The most striking of these improvements may be summarized as follows:

(1) The treatment of each State and Territory as a distinct entity—the statistics of the State being presented as a whole, and all its cities and counties being presented together in one volume, instead of being published in two separate volumes, as was the case in 1890. Accompanying the statistics of each State is a brief description of the origin and character of its leading manufacturing industries.

(2) A division of the statistics into those for the hand trades and those for manufactures proper, and a separate presentation of the statistics of each of these different forms of industry.

(3) A division of industries into fifteen cognate groups on the basis of the materials used, or similarity in use of products, thus permitting a proper estimate of the relative importance of each of the general branches of industry.

(4) A marked increase in the number of industries for which special reports were made. There were six such special reports included in the census of 1880, twenty in the census of 1890, and fifty-nine in the census of 1900. All of these reports at the present census have been accompanied by considerable historical and descriptive matter. This is the direction in which it has seemed most feasible to increase the general value and usefulness of a census of manufactures.

(5) The grouping of manufacturing establishments by the number of hands employed in each, and the further separation of those which use power from those which do not. Only by bringing together figures presented in different parts of the volume can the student of the census of 1890 make this comparison between establishments using power and those not using it.

(6) The elimination of duplications in the statistics which

show the gross value of products. It has not been possible to carry this improvement so far as is deemed desirable and necessary, but a great step in advance has been taken.

(7) The presentation of statistics for establishments according to the character of their organization.

(8) The extension of the function of the census into the field of statistical interpretation, without attempt or intention to enter the peculiar field of the economist or the sociologist.

The experience of the office has been a tentative one; a feeling of the way from census to census with distinct progress visible at each. This progress has necessarily extended the work beyond the mere gathering and presentation of statistical data into the field of intelligent interpretation; and as this function of a manufacturing census enlarges the work of the statistician, it brings him into constantly closer touch with the work of the economist and the sociologist. Nevertheless, the line of demarcation remains a clear one, the function of the Census Office being to ascertain the facts, and to throw all possible light upon their interpretation and upon the limitations surrounding the use of the figures. It is the function of the economist and the sociologist, observing these limitations, to draw conclusions from the data presented. But the statistician, in order to perform his part of the work, is entitled to go to all outside sources for information which will aid in the illumination and interpretation of the statistics themselves. This has been done at the present census to a degree not hitherto attempted.

In a paper read by Chief Statistician North before the National Association of Manufacturers on April 25, 1900, after bespeaking the sympathy and co-operation of its members in the undertaking just launched, and pointing out the advantages that would accrue from a successful issue, said:

"No census of manufactures yet taken has been free from very grave faults; but each succeeding census has been a vast improvement on its predecessor. Those in charge of the present work will be unequal to their opportunity, if they do not succeed in making the twelfth census the best in the series—a statistical photograph of the productive energies of the nation, which shall focus an industrial wealth and resource undreamed of in the past, as our opening vision of the twentieth century." The work is now ended; its results are at command, and you can all determine if the promise has not been fulfilled.

Book Notices.

International Catalogue of Scientific Literature. First annual issue. Published for the International Council by the Royal Society of London. D. Chemistry, Part 1. London: Harrison & Sons. 8vo, 468 pp. Paper.

The International Catalogue of Scientific Literature is an outgrowth of the *Collection of Scientific Papers*, published by the Royal Society of London. The suggestion to make such a catalogue is credited in the preface of the present work to Professor Henry, of the Smithsonian Institution, who brought the subject up at a meeting of the British A. A. S., at Glasgow, in 1855. The possibility of preparing a complete index of current scientific literature by international co-operation was taken into consideration by the Royal Society about the year 1893. As it was evidently beyond the means of this body to carry out the plan, conferences with scientific authorities of other countries were held, and in June, 1900, sufficient guarantees were obtained to warrant the beginning of the work. The material published is contributed by regional bureaus, which, so far, have been established in thirty countries. Each complete annual issue will cost £18 and consist of seventeen volumes. Single volumes will be sold at prices ranging from 10 to 35 shillings. The volume before us is priced at 21 shillings.

It is not necessary to speak of the value of such a publication. Every active worker in science knows the use of it, and it is fortunate that the financial aid necessary to its production has been obtained. Attention is called in the preface to the advisability of journals assisting the bureaus, by indexing each paper at the time of publication. It is to be hoped that editors and authors will co-operate actively along this line, so as to promote this most valuable enterprise.

The literary character and mechanical execution of the volume before us are excellent. H. L.

Elementary Chemistry. By Robert Hart Bradbury, A.M., Ph.D. New York: D. Appleton & Co. 1903. 329 pages; and Part II, *Experimental Work*, to accompany the text, 157 pages.

Among the numerous chemical texts for students in secondary schools that have been recently published, this book is undoubtedly one of the best and in some respects the most original.

The author's program is clearly stated in the preface, and a careful perusal of the book by the reviewer has satisfied him that the plan has been logically and successfully carried out.

It has been a genuine pleasure to read this independent account of the state of elementary chemistry as it exists *to-day*, by one who is not only thoroughly familiar with the literature of the subject, but who is also an experienced teacher.

The lucid, logical, and, withal, attractive manner of presentation cannot fail to make this manual an excellent and popular text for beginners, as well as profitable reading for more advanced students.

The introductory chapters are devoted to the familiar subjects of water, common salt, and atmospheric air, the discussion of which affords opportunities for explaining and developing the fundamental principles of chemical science. A very noticeable feature of the book is the easy and natural way in which the recent achievements of physical chemistry are made part of the foundation which is laid here; indeed, those paragraphs which deal with solution, acids, bases, and salts, ions, catalysis, speed of reactions, and the like, must be regarded as the gems of the book.

A fine balance is maintained throughout between the systematic and the historical methods of treatment. The former secures economy of effort on the part of the student, enabling him to master a great wealth of material; the latter, judiciously introduced, keeps his interest awake. It is only at the close of the text that the natural classification of the elements (the periodic law) and an historical sketch of chemistry are given. Both chapters are very readable.

The laboratory exercises, forming Part II, are, for the most part, those which are included in similar manuals. They are well selected and arranged, and the directions are very carefully given, the precautions necessary to insure success and avoid dangers being explicitly stated. The questions and problems at the end of each chapter in Part II are well adapted to promote the student's knowledge and interest.

The typography and illustrations are in harmony with the character of Dr. Bradbury's admirable production. H. F. K.

The Manufacture and Properties of Iron and Steel. By Harry Huse Campbell, General Manager of the Pennsylvania Steel Company. 8vo, pp. xxix + 862. New York and London: Engineering and Mining Journal. (Price, $5.00.)

The first edition of Mr. Campbell's work on this subject was favorably noticed in these pages several years ago. The present work, ostensibly a second edition, is in reality so completely rewritten and so enlarged by the introduction of new material, that it constitutes in reality a new book.

Among the many new features added to the present work are the divisions on the blast furnace, the open-hearth, and the use of fuels, while the pig and ore process, as well as the Bertrand Thiel and Talbot methods, are fully discussed. A new departure is the description of each separate important iron-producing district in the world, and no other publication has thus far attempted to cover this field. W.

JOURNAL

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ELECTRICAL SECTION.

Stated Meeting, held Thursday, January 8, 1903.

Automatic Electric Railway Signaling; Its Purposes; Also Past and Present Installations.

BY C. C. ROSENBERG, Signal Engineer, and H. S. BALLIET, Assistant Signal Engineer, Lehigh Valley Railroad, Bethlehem, Pa.

The purpose of automatic signaling on railroads is twofold: (1) To protect trains against collisions, running into open switches, cars fouling main tracks, indicating a broken rail, etc., thereby preventing loss of life and the destruction of equipment and merchandise; (2) facilitating traffic by being able to move more trains and at a higher rate of speed than by the system of spacing trains by time interval; also doing away with human agency, which at times errs in clearing signals, whereas the automatic signal is positive and can be considered a machine to perform a certain duty whenever actuated by a train in the block.

In treating the subject of past and present installations, it is proposed to subdivide it into two parts: (1) To show the method of installation and apparatus from the inception of automatic signaling to a period when they could be considered reliable and beneficial for railroad purposes; (2) to show the improvement in appliances to overcome difficulties experienced by those who were the pioneers in the art, as well as to be able to reduce the cost of operation; at the same time, it is not intended to convey the idea that all of the original devices have been discarded, as there are a number of installations placed in service years ago that are still giving good results, though no doubt later designs are being substituted when repairs are necessary.

In all of the latest developments of mechanism and application the first principles, either separate or combined, are still adhered to.*

PAST INSTALLATION.

It is maintained by some that the credit of inventing the first system of automatic block signals belongs to Mr. Wm. Robinson and by others to Mr. Thomas S. Hall. Both were working upon the development of the system as early as 1866; during this year, Mr. Hall installed on the New Haven Road, near Hartford, Conn., a few signals for experimental purposes; in 1871 he installed a number of disc signals on the New York and Harlem, Boston and Albany and on the Eastern, now part of the Boston and Maine system. During this same year Mr. Robinson put up an experimental installation (clock-work disc) at Kinsua, on the Philadelphia and Erie Railroad. All of the above installations are known as the wire-circuit system, none of which, however, as first installed, worked in an entirely satisfactory manner.

The signal as installed by Mr. Hall was constructed as follows: On top of an iron mast is placed a wooden case, inside of which is a disc of very light weight, consisting of a circular wire frame covered with red silk or serge. The case has a circular opening in front and back, covered with glass, through which the position of the disc can be seen. When the disc is down, it indicates—Danger, stop; and when it is drawn up, it indicates—Proceed, block clear. In order to more readily distinguish the position of the disc, the case is painted black and the glass in the back of the circular opening, white.

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*At the close of each part of the discourse, there were shown by stereopticon views the various types of mechanism applied for the operation of the different signals in use and the details described.

For the night indication, a light is placed back of the circular openings and its rays are directed through the disc, which, being translucent, indicates the position of the signal. The disc is fastened to an arm of a revolving armature of an electro-magnet and is raised to the proceed indication when the magnet is energized; the disc returns to the stop indication by gravity.

The electro-magnet, commonly known as signal magnet, is operated directly by a primary current delivered from a battery located at a suitable place within the block limit by means of a wire placed on poles. The circuit is controlled by a device known as a track instrument, which has levers placed at right-angles to the rails, in such a position that the wheels depress the levers, which in turn causes a second lever to be raised, opening or closing the circuit through a contact spring. The discs are held normally at proceed and the entrance of a train to the block section breaks the circuit in the track instrument, de-energizing a relay, thus dropping its armature, which action opens the battery and de-energizes the signal magnet, thus setting the disc to the stop indication; this indication being maintained until the train passed over a second track instrument located about 2,000 feet within the limits of the next block, the operation of which closed a circuit, energizing the magnets of the relay through the battery, restoring its armature; but the signal instrument remains de-energized until the entire train has passed over the track instrument because its circuit is cut out as long as the contact spring remains closed.

In this system, when a train enters a siding to permit another to pass, and after such train had cleared the fouling-point and the switch was again set for main track, it was necessary to operate what is known as a clearing key in order to restore the signal to the proceed indication for the following train. On the other hand, in order to protect a train coming from a siding to the main track, a circuit-breaker attached to the switch-point of the outlet turnout opens the circuit of the battery and sets the disc to the stop indication.

The wire circuit does not indicate the presence of a detached car or part of train should it remain in the block, because the forward portion, leaving the block, restored the signal back of the separated portion to the proceed indication.

In an effort to better protect traffic, should failures occur, two signals were installed—the "indicating" and the "stop" signal. The indicating signal was equipped with a blue disc for day and a blue light for night, the normal position being at proceed. About 1,500 feet ahead of the indicating signal was located a home or stop signal, standing normally at stop. An approaching train, when passing the indicating signal, would, if the circuits were intact, set the signal in the caution position in the rear of the train, at the same time causing the electro-magnets to set the stop signal in the proceed indication. The object of this was that if the system were out of order, the stop signal would not clear, and if such were the case, the indicating signal would remain in the caution position, which would be a notice that an approaching train must stop before arriving at the home signal.

Mr. Frank L. Pope made some experiments on the Boston and Lowell Railroad in 1871; he also had a signal on exhibition at the Centennial Exposition in 1876, where he had a section of track submerged in water to show the efficiency of the track circuit. There does not, however, appear to be any data available in either of these installations how he bonded the track, what insulation was employed or how he operated the signal.

In 1872 Mr. William Robinson had issued to him letters-patent, for what was, no doubt, the broadest and most controlling patent ever issued on automatic railroad signaling, the papers covering the invention of the track circuit. He divided the track into sections, placing a battery at one end and a relay through which to control the signal circuit at the other end. This is the track circuit as used to-day. Mr. Robinson first applied it on the Philadelphia and Erie Railroad early in 1872.

There was another form of treadle or circuit-closing signal device known as the Rousseau system, invented by David Rousseau in 1873. The signal was operated and controlled by a circuit-closer located underneath the rail. The disc when set at right-angles with the track indicated—Danger, stop; and when set with the track, no disc was visible and indicated—Proceed. At night a lamp was placed in the back of the case, which gave a red light for stop and white for proceed. The disc was operated on a revolving vertical shaft controlled by a magnet and its armature. A counterweight which required periodical winding kept the disc from remaining at proceed should the current be cut off. This design of signal was afterwards approved and worked in connection with the track circuit.

In 1879–80 the Fitchburg Railroad adopted the rail (track) circuit signals. This was the first practical installation, other than for experimental purposes, of its kind, and was used in connection with the automatic clockwork signal. The arrangement in this system is as follows: The track battery is placed underground (as a protection against freezing) at the outgoing end of a section; the current is conducted through bonded rails and through a relay at the other or incoming end of the section. This relay controls the local signal circuit through its contact point. At switches, the current (track circuit) is led through a circuit-breaker, which is opened whenever a switch rail is moved. The circuit is also led through the rails of side tracks for a short distance, so that trains entering these tracks are protected, the same as when on the main track, until all of the cars are clear of the fouling point.

The signal is a wooden disc fixed on a vertical spindle, and is turned one-fourth revolution by a weight every time the circuit is made or broken through a relay point. The weight is suspended within a hollow mast and passing over a sprocket wheel mounted on a shaft, one end projecting from the face of and near the bottom of the instrument, and having a squared end to which is applied a crank or key, thereby enabling the instrument to be wound up periodically. A lamp set on the upper end of the spindle to which the disc is fastened displays indications to correspond to the position of the disc. The local battery which is delivered through the track relay point passes through a pair of electro-magnets (signal magnets) located upon the upper right-hand side of the instrument and above the magnets; pointing to the left is the armature bar, which, as its free end is alternately raised and lowered by the charging and discharging of the signal magnets, releases one of the detent toes and holds the other raised. The office of these toes is to engage and disengage the pawls with the crosshead, which is mounted on a shaft which carries one of the train gears that change the vertical revolution derived from the weight of the horizontal position, this position being required to operate the disc. There is an arrangement applied in such a manner that when the weight has nearly reached the bottom of the pole, the local circuit is automatically broken and the disc will remain in the stop position. The disc when it indicates stop stands at right-angles with the track; when at proceed, edgewise, and is not visible. The signal mast is placed about 150 feet within the block section, so that an engineman, when approaching it and finding the disc in the proceed indication, may see it change to the stop indication.

In the above installation, should a car remain on the track, a rail be removed or broken, bond wires broken off, battery become exhausted or removed, wires broken between track battery and rail or relay and rail, the signal will remain in the stop indication, because the relay magnet will then be demagnetized.

As the clockwork automatic track circuit signal gave good results, it was found advisable about the year 1884 to install what is known as an "overlap," which to a certain extent takes the place of a distant or caution signal. These circuits were first used on the Boston and Albany. The track and controlling circuits for such an installation are identical to those described on the Fitchburg Railroad, except that another track section is provided, this section extending from 1,000 feet to 2,000 feet into the next block, causing two signals to be held in the stop indication until the rear end has passed the overlap.

The Fitchburg Railroad placed in service 12 miles of electro-pneumatic (semaphore) track (rail) circuit in the year 1879, this being the first installation of this design. At the top of an iron mast, about 24 feet high, is placed a semaphore arm, to which is attached a rod 3 feet long connecting it with a yoke fastened to a piston actuated by compressed air. The air is controlled by an electro-magnet, the armature of which opens and closes a valve. The signal is brought to the proceed position by the attraction of the armature of the electro-magnet becoming energized through a local battery, controlled through the contact point of a track relay. The circuit for this track relay is the same as the one described in connection with clockwork track circuit signals. The de-energizing of the valve magnet closes the valve and opens an exhaust, allowing the air to escape from the cylinder in which the piston is located, a counterweight restoring the signal to the stop position.

In this installation, a circuit-closing spring is attached to the piston rod in such a manner as to open an auxiliary circuit when the signal has returned to the stop position, so arranged as to ring bells at certain switches, which is intended to announce the presence of a train in the block section. This applies, however, to only a few special signals.

The air which operates the arms is applied by a 1-inch pipe, running between the tracks, located below the surface of the ground. At each signal a $\frac{1}{4}$-inch branch is connected with the main pipe and leads to a reservoir at the bottom of the mast, which holds sufficient supply to make about twelve operations of the arm should the main supply fail. When occasion requires, the supply for each arm can be shut off by a stop-cock, which is located in this branch pipe. Stop-cocks are also supplied in the main pipe about every half mile to assist locating leaks, etc.

The reservoir at bottom of mast is connected with a valve and cylinder by a $\frac{1}{4}$-inch pipe. The air is placed at 60 pounds pressure, but can be used as low as 40 pounds. It is supplied by a pump of similar construction to that employed for the Westinghouse air brake.

The air first passes through a coil of pipe to cool it, thence into a reservoir with which is connected a blow-off cock to remove the condensed water. From this reservoir it is delivered into the 1-inch main.

In 1884, 13 miles of this design of signal was placed in service on the West Shore Railroad; the same system was also applied on the Pennsylvania Railroad, between Wilkensburg and East-Liberty, the same year. Both of these installations were, however, more complicated than the one described on the Fitchburg.

This system, as operated on the West Shore and Pennsylvania Railroads, embraced features which had not as yet been employed in automatic signaling, viz., the signal being placed exactly at the entrance of a block and having a distant signal for each home signal. The distant signal, being located at the beginning of the preceding section, is placed on the mast carrying the home signal. The upper signal, being the home, is painted red; the lower signal, being the distant, is painted green, having a fish-tail end. The distant refers to the next home signal in advance. The night position is indicated by lamps placed on brackets so fastened to the poles as to throw their rays through a red lens located in the blade grip casting (which are also used as counterweights) when the signals are in the stop position, and through a green lens when the blades are in the proceed position.

There is a line wire between the home and its distant signal, so arranged as to reproduce the movements of the home. There is connected with the home signal, located on the same mast with a distant, a shunt, which cuts out the magnets of the distant signal. This is done to avoid the home signal being in the stop position and the distant in the proceed position. All line wires for distant signals and local battery are grounded to the main air pipe. By this installation, with a train in the block, there is always displayed a home at stop and two distants at caution.

The signals just described are controlled and operated by compressed air delivered at each mast, as described on the Fitchburg installation. The cylinder has, however, been remodeled and improved. There is an electro-magnet with a diaphragm-like armature to which is attached a long pin ; this pin opens and closes a valve called "pin valve." The 60-pound air pressure is constantly maintained at this pin valve, which controls the admission to the cylinder. The piston of this cylinder is connected to the blade directly (as on the Fitchburg) or through a balance lever, and in its normal condition is in the upper end of the cylinder, being held there by the counterweight or balance lever.

When the relay contact is closed, thus delivering current from the local battery through the signal magnet, the armature opens the valve and allows the pressure to enter the cylinder and operate the piston. When the signal magnet is energized the exhaust valve is closed. The breaking of the circuit through the signal magnet causes, the admission valve to be closed and opens the exhaust valve, allowing the signal to return to the stop or caution position by gravity.

In 1887 the New York Central and Hudson River Railroad placed in service 8 miles of double-track disc signals controlled by the wire circuit. This is the first installation where a distant signal is used in conjunction with a home, each being located on a separate mast, both working simultaneously.

Early in 1887, Robert Black placed in service on the Manhattan Elevated Railroad a series of automatic block sections. These blocks are operated under the absolute rule. The semaphore arm, being somewhat shorter than on any previous installations, is fastened to an iron mast and is provided with an iron shield, behind which the arm is hidden when it is in the proceed position. The shield is painted black, so that the proceed position is indicated by the absence of the blade rather than by its position. These signals are controlled by track instruments of peculiar construction, a lever being placed outside of the rail which operates a rocking shaft, which is connected with a series of pipe mounted on pipe carriers. The track-instrument lever is depressed by the tread of the wheels as they pass over it, thus transmitting motion to the blade. The pipe connection leads to a bell crank, through a motion plate located at the foot of the pole and operates an up-and-down rod which moves the blade in the required direction. In order that there may be no unnecessary jar to the various parts, the rocker-shaft arm is supported by means of a rod having on one end of it a strong spiral spring.

PRESENT INSTALLATION.

Very little progress was made in automatic signaling between the years 1887 and 1893. This was probably due to various reasons, viz., traffic conditions did not warrant it; managers evidently considered signals a luxury and not a necessity, or were skeptical as to getting value received, etc. Inventors of signal devices, however, vied with each other in getting out improvements on existing appliances and bringing to the front new devices. In this they were most successful.

In order to describe the different devices brought forward during this period, it will be necessary to begin with the installation of electro-pneumatic automatic block signals on the Pennsylvania Railroad as installed since 1889 (home and distant on same mast), which is the most approved power installation of its kind. The air which is compressed for numerous interlocking plants is also utilized for the block signaling. A track circuit controls the valves for the air operating the arms. The arms are set normally in the proceed position, the top arm being painted red and the lower arm green, with lenses of corresponding colors for night indications.

The circuits controlling these signals are similar to those already described, except that there is no line wire between a home and its distant signal, and are operated by means of a simple and polarized relay combined.

In 1891 discs were placed in service on the New York

Central and Hudson River Railroad, also the Kansas City and Fort Scott Railway. The apparatus and circuits are practically the same as already described, except the normal indication, which is at stop; the approach of a train energizing the signal magnets through the proper circuits, causing the disc to be drawn to one side, thereby indicating proceed; the disc is returned to the stop (normal) indication by gravity. The night indication is given through a glass disc provided at the upper extremity of the revolving armature of the signal instrument. This night glass is of the same color as the cloth disc which gives the day indication. The signal case is provided with suitable openings to correspond.

In connection with these signals, there is a series of indicators or miniature signals, located at side-tracks and cross-over switches, the operation of which indicates the approach or presence of a train in the block. The indicators are held normally at proceed by current taken from the signal circuits to which they are auxiliary, while the disc is in the stop position. When the disc is at proceed, the indicators are at stop because the controlling circuits have been opened, due to the presence of a train.

The Cincinnati Southern Railroad has a number of Union enclosed disc signals in service controlled by a track circuit. The banner is made either of cloth or aluminum, in the center of which is placed a celluloid disc for the night indication. The operation and control of this signal is similar to all other banner signals.

The Lehigh Valley Railroad installed, in 1893, a number of track-circuit signals which differed somewhat from previous descriptions; a red or stop disc is placed at the top of a mast and below it a green or caution, which show normally the stop and caution indication and are set to the proceed indication by the approach of a train. The caution indication is controlled by a wire running from its home through a relay point, the magnets of the relay being in series with home on the same mast with the distant. By this combination, the distant will indicate—proceed, provided there is no train in its home block and the home on the same mast with the distant is in the proceed indication. These circuits have, however, been improved to some extent in later installations, namely, the caution indication is controlled through a circuit closer located on the magnets of the home signal, so arranged as to be open when the disc is in the stop indication and closed when in the proceed indication.

To assist in making good contacts for this circuit closer and reduce to a minimum the current output from the primary cells which operate the signals, there is arranged a 500-ohm coil, which is cut in automatically when the disc has reached the proceed indication. With this coil in service, there is a current of less than one one-hundredth of an ampere utilized. All switches and crossovers are protected by visible indicators supplied with a red disc.

In all signaling on this road since 1896, track sections are protected with two relays, one at each end of the section, the one at the entrance being 16 ohms resistance and placed in multiple with the track battery; the other, a 4-ohm, at the outgoing end of the section. This installation is carried into effect to meet the various conditions arising from earth currents, which are prevalent. It will be noted that a train entering a track section short-circuits the track battery and the 16-ohm relay, thereby opening the controlling signal circuits. The 4-ohm relay repeats this opening process. All line wires run through switch boxes or circuit-breakers, and go to the end of the block where the governing battery is located.

Signal experts had been working for some time to devise a signal other than the disc type, as some objections had been raised, that under certain conditions the indication could not be readily discerned by enginemen on high-speed trains. It is true the electro-pneumatic semaphore type had been in successful operation for some time. Railroad managers, however, desired a position signal that could be installed either singly or in small groups; for installations of this kind it would not be economical to install power stations.

During the year 1893 an electric motor semaphore signal was patented by Mr. J. W. Lattig. The first signal of this type was placed in service on the Central Railroad of New Jersey, near Easton, Pa., and operated successfully for several years. The arm is moved from the stop to the proceed position by a $\frac{1}{6}$-horse-power Crocker & Wheeler electric motor, which is supported on a bracket fixed to the side of the mast below the signal arm. When released, the arm is returned to the stop position by gravity.

To operate the motor a potash battery of suitable e. m. f. is used. This battery is placed in a deep well to keep it from chilling under extreme weather conditions. When the motor is operated it winds up a cable, which lifts a counterweight attached to the signal arm, thereby causing the arm to be drawn to the proceed position, and is held there by an electric brake. The motor is controlled through a track circuit similar to other installations. The arms are provided with ball-bearings to reduce the friction and make the various operations more freely.

After this device had withstood the various tests, a number of them were installed on the Illinois Central Railroad in 1896.

The way had now been opened for a new field, viz., to operate signals by other than electro-magnets. The development of the electro-motor since that time has been rapid, and there are to-day in service the following designs:

In the Union electric semaphore many of the possible interruptions to automatically operated signals were anticipated, particularly the placing within an iron pipe, the up-and-down rod connecting the motor and its mechanism with the arm, thereby preventing the freezing at connections in extreme weather. An arm is raised by a motor of low resistance, and is connected to the semaphore in such a manner as to move it to the proceed position. The motor is connected through a set of gears to an endless chain. There is a finger or tooth provided, whereby the arm is raised whenever the circuits are intact, and close the battery through the slot magnets.

The office of the slot magnets is similar to the signal magnets and the air valves described heretofore. The motor is usually operated by a contact controlled through relay points, and is opened when the arm of the mechanism has reached the full stroke required to set the semaphore arm to the proceed position. Where this signal is installed on the home and distant plan, the distant is controlled by the wireless principle, described in connection with the Pennsylvania Railroad installation. It requires 16 cells of caustic potash battery to operate the same.

By introducing a compound-wound magnet for the slot, the same battery is used to engage the signal and control its operation in addition to furnishing the current for the motor. One motor is required to operate both home and distant blades.

The Wilson motor, semaphore, was next introduced. This application embraces an endless chain, which is set in motion by a $\frac{1}{6}$-horse-power series-wound Crocker & Wheeler motor, through a set of gears.

The clutch magnet is fastened to the up-and-down rod, and travels with it. When current is delivered through the clutch magnet, a contact is closed which starts the motor and the clutch is drawn upward by engaging the tooth of a sprocket wheel in the endless chain. When the semaphore arm has reached the proceed position, the motor current is cut off automatically, and the signal is held in that position by the armature of the clutch magnet remaining engaged. The semaphore is returned to the stop position by gravity. The distant signal is usually operated by a wire running from its home to its clutch magnet and controlled through a circuit-closing spring on the home arm, so as to make it necessary for the home arm to be in the proceed position before the clutch will be energized. By a special shifting apparatus, the motor is thrown into service and the distant blade operated.

Like the home, the distant arm is returned to caution by gravity when the clutch magnet is de-energized. This system requires 12 cells of caustic potash battery to operate each motor. The clutch magnets are controlled through circuits, which get their current from a separate battery, generally 10 cells; this, however, depends largely upon the length of the blocks.

The motor mechanism, known as the Coleman design, is constructed as follows:

A series motor of low resistance operates through a pair of gear wheels, known as a clutch gear, to which is fastened a set of pawls so regulated as to operate the signal arm to the required position. Mounted on a shaft are two loose arms; to the one on the right of the gear is fastened the up-and-down rod of the home, and to the one on the left, the up-and-down rod of the distant signal. The arms are engaged with the pawls by an armature. The clutch magnets are permanently fixed to the motor mechanism frame. When there is a current delivered through these clutch magnets, the armature is engaged, which allows the arm to be moved into the position required to move the semaphore arm to the proceed position. There is a second armature on this clutch magnet which closes the motor circuit and controls the operation of the same. Attached to the arm operating the blade is a rod controlling a circuit-breaker which stops the motor as soon as the blade movement is completed. The signal is held in the proceed position as long as there is current through the clutch; it returns to the stop position by gravity. The battery arrangement is similar to that of the Wilson motor signal.

There is an older design of the Coleman motor mechanism in which the clutch is attached to the moving arm instead of being stationary; otherwise the mechanism and its operation is similar to the one just referred to.

All of the motor signals heretofore mentioned are in service on what is known as the two-position signal, viz., the arm in the horizontal position or at right-angles from the mast, as seen from an approaching train, denotes stop; when at 45°, 60° or 90° below the horizontal (according to the standard practice), denotes proceed. At night this indication is reproduced by a light through the lens.

There is in service a three-position electric motor signal, that is to say, one semaphore arm can be set at three different positions, viz., horizontal, Stop; 45° below the horizontal, Caution; 90° below the horizontal, Proceed. Each signal is controlled by a track circuit immediately in front of it, as already noted, but the control for the distant position of the signal in the rear is maintained through the medium of a line wire located on poles.

The signals are worked by electric motors of $\frac{1}{12}$-horsepower, one at each signal. The motor moves the signal arm by means of an apparatus analogous to the electric slot, termed the slot instrument. This instrument consists of a sleeve, which is directly connected with the up-and-down rod of the blade, inside of which is fitted a rod. This rod has a number of teeth so arranged and located as to engage the teeth of a pinion driven by a motor. At a given point the sleeve is provided with an opening, through which the armature of the slot magnet locks it (the sleeve) to the rod just mentioned. When the slot magnet is energized, owing to the track relay being engaged, the motor will operate the blade to the proceed position, it being held there by the lock introduced by the slot armature. When the slot armature is disengaged, the arm returns to the stop position by gravity, the lock in the up-and-down rod having been withdrawn. In order to raise the signal, the motor transmits its power through a series of gear wheels to a pinion which has a given number of teeth omitted, so as to make it possible to return the arm to the stop position without running the motor mechanism backward.

The various positions of the arm are maintained by pawls, so arranged as to hold the weight of the semaphore arm as long as the slot magnet is engaged. In order that there may be no undue strain to the mechanism when the arm is returned to the stop position, a dash pot or air cushion is provided.

The circuits operating the motor and energizing the slot magnet are controlled by the movement of the up-and-down rod, operating the semaphore arm.

Some of the motors on the installation of the P. F. W. and C. Railway are operated by six type 5D accumulator cells, four signals being located on a bridge, all of which feed from this battery. These cells, as well as track battery (also storage) for a distance of 35 miles, are charged by a power circuit located on poles. Still another installation on this system has storage of the same type charged by primary cells.

On the Alleghany Mountains, near Altoona, Pa., is found the only installation having two distant signals on the same mast with the home. On account of the heavy descending grade, it is important that enginemen have as much information of the condition of the blocks in advance as can be given. As in all other Pennsylvania Railroad installations, the upper or stop signal relates to the block directly in advance; the distant immediately below the home refers to the second, and the lower, to the condition of the third. It will thus be seen that ample information is given to successfully operate at high speed the many heavy trains using this line. Line wires located on poles control the distant for the third block. The entire installation is of the electro-pneumatic type controlled by track circuit.

The largest single track automatic block signal installation in service is on the Cincinnati, New Orleans and Texas Pacific. All of the later types of signals are here represented. No distant signals are used, the overlap being substituted. All masts are set 210 feet within the block section, so that the enginemen may see the signal move from the proceed to the stop position. The circuits are maintained through line wires located on a pole line. Caustic potash and bluestone battery are used for the various circuits.

On the Southern Pacific there are in service a number of electric motor signals of the Union type to protect single track movement; no distant signal is used, the overlap system being in service. The wires controlling these signals are placed on a pole line. All masts are set directly at the entrance to the block. Signals for both directions are directly opposite. The overlaps are about 800 feet long. The operation of this system is similar to that on the C. N. O. and T. P. Railroad. The motors are operated by four cells of portable storage battery, and are charged about once a month, by taking them to the several power plants, installed at specified points along the line; these plants are also used for other purposes.

There is in service on the Lehigh Valley Railroad a single-track automatic block system, in which the home and distant signals are placed on the same mast at the entrance to a block. The signal for the opposing direction is from one-half to one mile distant. These signals are controlled by wires placed on a pole line. They are operated by caustic potash battery for signals and bluestone for track circuits. In this installation there is always a piece of track equivalent to one block between two opposing trains, which is guarded by a signal in either direction. The distant signal is substituted for the overlap previously mentioned.

Until 1899 but two colors were available for night indications that could be distinguished at a distance, viz., red for stop; green for caution. In a few cases, however, green was substituted for proceed, and either a combination of red and green side by side or red applied for caution; in the latter case, the day indication being a green blade and a red light at night.

To the New York, New Haven and Hartford Railroad belongs the credit of taking the initial step by adopting a yellow lens for the distant night indication. In the year 1899 they placed in service red for stop, yellow for caution, and green for proceed, which practice is fast coming into favor.

The Chicago and Alton Railroad, in 1900, installed a number of electric motor semaphore signals, standing normally at stop. The motors are operated by a caustic potash battery. The home or stop signal is painted white with a black stripe near the outer end and parallel to it. The distant or caution blades are fish-tail and painted yellow with two black stripes. These stripes correspond with the shape of the fish-tail. The night indications are red for stop and yellow for caution, with green for proceed. In this installation the distant signal is placed on a separate mast a suitable distance in the rear of its home signal.

The distant signals are set to the proceed position at a point 1,200 feet before reaching it; also at the same time the corresponding home. Audible indicators (bells) are placed at all switches and announce the presence of a train when it sets the distant and its home to the proceed position, and will indicate until the block is clear. The distant signals are controlled by a polarized relay, operated in conjunction with line wires.

The Central Railroad of New Jersey, and Delaware, Lackawanna and Western, in 1900, installed a number of electric motor signals, home and distant on the same mast. The semaphore arms stand normally at proceed; a simple and polarized relay is in use, the simple side of the relay controlling the home signal, and the polarized side its distant through the track by introducing a pole changer on the up-and-down rod of the home signal; this pole changer reverses the polarity of the track battery, thereby giving the distant indication after the home has resumed the proceed position.

In 1900 there was installed on the Boston Elevated Railroad a system of electro-pneumatic signals, such as already described, except that they are controlled by a special track circuit arrangement. This is an electric railroad, and in order to make it possible to operate a track circuit, the one rail is used for a return power circuit and is reinforced by a copper wire. Polarized relays are so arranged as to use the return rail and an independent wire for the return circuit. The relays are actuated similar to other track circuit installations, except in this case there are no local or track batteries. The contacts of these relays control the electro magnets of the pin valves, as explained in regular pneumatic installations. At each home signal which stands normally at proceed, there is a trip arranged to automatically open the air pipes on the train and apply the brakes should the motorman neglect to obey the stop indication. Each signal is placed 180 feet in the rear of the beginning of its control track section, or in other words, the front end of a train must be 180 feet by the home signal before it will set it to the stop position. This is necessary in order that the rear car may be beyond the trip, which automatically stops a train which may attempt to pass a home signal.

A number of railroads have installed what is known as the semi-automatic or slotted signal. The most simple design is an arrangement by which the up-and-down rod is made or broken by the intervention of a tooth controlled by an electro magnet. The upper rod is arranged so as to allow the lower rod to travel within its hollow part. A suitable notch is cut to allow the armature tooth to engage the rod when current is delivered through the magnet, thereby allowing the leverman to pull the signal to the proceed position. The slot magnets are controlled through a track circuit relay, and as soon as a train enters the section, demagnetizes it, thereby releasing the tooth, allowing the arm to return to the stop position by gravity. There are many installations in which a circuit breaker is so arranged as to make it necessary for the leverman to raise a latch on an interlocking lever before the arm can be electrically engaged and pulled to proceed. Still another arrangement is where the proceed signal cannot be given until a train is actually approaching either the distant or the home signal. This is accomplished by track circuit relays, engaging the slot at specified points.

In this system all slotted semaphores are held normally at stop. In all cases described, a train, after passing under a home signal, keeps the slot magnet de-energized, making it impossible for the leverman to operate the arm, although the lever is free to be moved. It takes from eight to twelve volts to accomplish this function, depending largely upon the length of the sections and minor conditions. In addition to these so-called electro-mechanical slots there is an electric slot in service. This is used in connection with the All-Electric interlocking. The magnet of this slot is of high resistance, and so arranged that an approaching train will receive a proceed signal if the slotted or block section is clear. The current (usually 110 volts) is supplied by a generator or storage battery, the arrangement of circuits being similar to those above described.

In 1901 a local power signal was invented, operated by means of compressed liquid carbonic acid gas, supplied in tanks. In this design, unlike previous descriptions, the power supply is localized, each signal mast having its distinct reservoir. The long-established principle of a separate supply of current for each circuit is here carried into effect.

A cylinder about 5 inches long, constructed of suitable metal to prevent rusting, and supplied with a piston of the same material, operates the semaphore arm, and is directly connected to the up-and-down rod. A port of suitable design is placed between the reservoir and the cylinder, the office of which is to control the supply of gas, and is operated by one of the armatures of a double and electro magnet. When this magnet, commonly known as the clutch, is energized, it opens the port, allowing the gas supply, usually 50 pounds, to enter the cylinder, which causes the piston to move the arm to the proceed position. As soon as the arm has reached this position the port is closed automatically by the other armature, thereby allowing the gas supply in the cylinder to be exhausted. This armature also holds the signal in the proceed position. When the clutch is de-energized, the arm returns to the stop position by gravity. The control of the clutch is affected by means of the track circuit, as all other installations. The clutch is operated by primary cells, and requires about 5 volts for blocks 1 mile in length.

Liquid carbonic acid is a commercial article, and for signal purposes is supplied in tubes or tanks about 7 feet long, 8 inches in diameter, each containing about 50 pounds. This gas is chemically pure CO_2, liquefied by means of high pressure, assisted by low temperature, as received in the reservoir and compressed to 900 pounds to the square inch, which reduces it to a liquid form.

The number and type of signals in use on the various railroads in this country are classified as follows:

Enclosed disc	1,894
Clockwork disc	1,041
Electro-pneumatic	3,420
Motor	7,346
Electro gas	248
Total	13,949

The writers of this article have endeavored to define the various designs and systems in a concise form, without entering too closely into detail; they are indebted to the various technical papers and authors of works on signaling for some of the detailed data required in clearly defining the functions of the different systems.

ARTIFICIAL CAMPHOR.

The manufacture of pure artificial camphor upon a commercial basis has been discovered by Mr. E. Callenberg, of Germany, technically known as chlorhydrate of terebinth. This substance possesses many peculiar properties, which will render it of great value for many commercial purposes, the most important of which is that it is soluble in nitro-glycerine; and as it reduces the maximum temperature of this dangerous substance during explosion, it is considered that it will do much to render considerably more safe the manufacture of high explosives such as nitro-glycerine. Not only does it reduce the temperature of explosion, but it lowers the freezing point of the substance to a very marked extent as well. Pure nitro-glycerine freezes at + 8 deg. centigrade, but when a 3 to 5 per cent. solution of the chlorhydrate of terebinth is added, the freezing point drops from —10 deg. to —15 deg. centigrade Furthermore, guncotton and many other soluble explosives can be easily dissolved at a low temperature in a solution of chlorhydrate of terebinth and nitro-glycerine, the resulting substance being a highly improved quality of gelatine-dynamite.—*Scientific American.*

ALUMINUM AND BAUXITE.

The report on aluminum and bauxite for 1902, by Dr. Joseph Struthers, has just been issued by the United States Geological Survey. The production of aluminum in the United States during 1902 was approximately 7,300,000 pounds, as compared with 7,150,000 pounds in 1901, the sole producer being the Pittsburg Reduction Company, which has large plants in operation at Niagara Falls and at Shawingan Falls, Quebec, Canada, and is installing a large plant on the St. Lawrence River, near Massena, N. Y.

The chief use of aluminum is for the transmission of electrical currents and for alloys possessing exceptional physical and chemical properties, though a considerable part of the output is manufactured into domestic articles of various kinds. Two growing uses of the metal are for lithographic work and for the production of intense heat by the combustion of the metal as powder.

The production of bauxite during 1902 amounted to 27,274 long tons, as against 18,905 long tons in 1901. Georgia yielded the greater bulk of the product, the remainder coming from Alabama and Arkansas. The consumption of bauxite in 1902 amounted to 43,112 long tons, as compared with 36,218 tons in 1901.

The domestic production of alum and aluminum sulphate in 1902 amounted to 88,614 short tons, valued at $2,238,171, as compared with 82,496 short tons, valued at $2,026,554 in 1901. The imports in 1902 were valued at $16,808, as compared with $20,781 in 1901.

The Induction Motor and Its Engineering Capabilities.*

[*A Thesis Presented to the University Faculty of Cornell University for the Degree of Doctor of Philosophy.*]

By George L. Hoxie.

Part One.

THE INDUCTION MOTOR.

Definition.—The induction motor, as its name implies, is a motor that depends for its operation upon the principles of "induction." As generally used, this term means the production of an effect at some point by a cause located elsewhere, no apparent mechanical connection existing between the cause and the effect.

Thus, given an electric charge on a conducting body, if a second conductor be brought into the neighborhood, induced charges, of opposite signs, will appear on those surfaces of the second body which are nearest to, and most remote from, the originally charged body.

Also, if a current be established in one of two neighboring closed conducting circuits, a current, called an induced current, will flow momentarily in the second circuit.

Or, if a magnet be created in the vicinity of a mass of soft iron, induced magnetic poles will appear on the latter.

Many similar examples of induction might be given. Any motor that depends primarily upon such phenomena for its operation may be properly termed an induction motor.

Practical Form.—Several varieties of purely induction motors have been devised, but only one possesses any practical interest. In this class, the magnetic forces produced by the field due to an induced, or secondary, current reacting upon the field produced by an inducing, or primary, current, are made to do work.

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* The writer wishes to thank Prof. Harris J. Ryan for suggestions and advice received prior to the inception of this thesis, and from time to time during the progress of the work.

Also to acknowledge his indebtedness to several friends, through whose kindness it was possible to obtain the data of construction and performance which form a part of this paper.

Both primary and secondary currents are of necessity alternating, since it is only by a change in one current that another may be induced. It is also necessary, in order to get a continuous rotary motion, that the currents present should be polyphase currents. This does not necessarily imply that polyphase currents should be supplied to the motor, although it is usually best that this should be done.

The elementary theory of induction motors is quite simple, but an extended study of their behavior involves the consideration of some very complex relationships, and is correspondingly difficult. In fact, such a study cannot be made at all without the use of approximations which affect to a greater or less degree the accuracy of the result. This state of affairs is not indeed peculiar to the induction motor. Hardly any of Nature's phenomena are so simple that a mathematical study of them can be entirely complete. Obviously the results of such a mathematical investigation are only correct to the same degree as were the original assumptions. It is therefore of the utmost importance that one should determine as accurately as possible the degree to which such approximations as are necessary are likely to affect the final result.

Study of a Particular Motor.—Before taking up any theoretical matters connected with the induction motor, it will be well to make a very careful study of a particular motor, not from a mathematical standpoint, but with a view of actually determining what goes on in the iron and copper of which it is composed. Such a study will serve to make clear the effect of some of the customary approximations used in the mathematical theory of the motor, and will enable one to form a fairly correct idea as to their propriety.

The motor chosen for this detailed study is one for which the writer was able to obtain nearly all of the electrical dimensions. Its specifications are as follows:

Horse-power	75
Revolutions per minute	250
Outside diameter of primary core	40 in.

Inside diameter of primary core	32·09 in.
Outside “ “ secondary “	32 “
Inside “ “ “ “	26 “
Gross laminations parallel to shaft	10·5 “
Ventilating ducts “ “ “	1 “
Net laminations “ “ “	9·5 “
Volts primary pressure	220
Phases	3

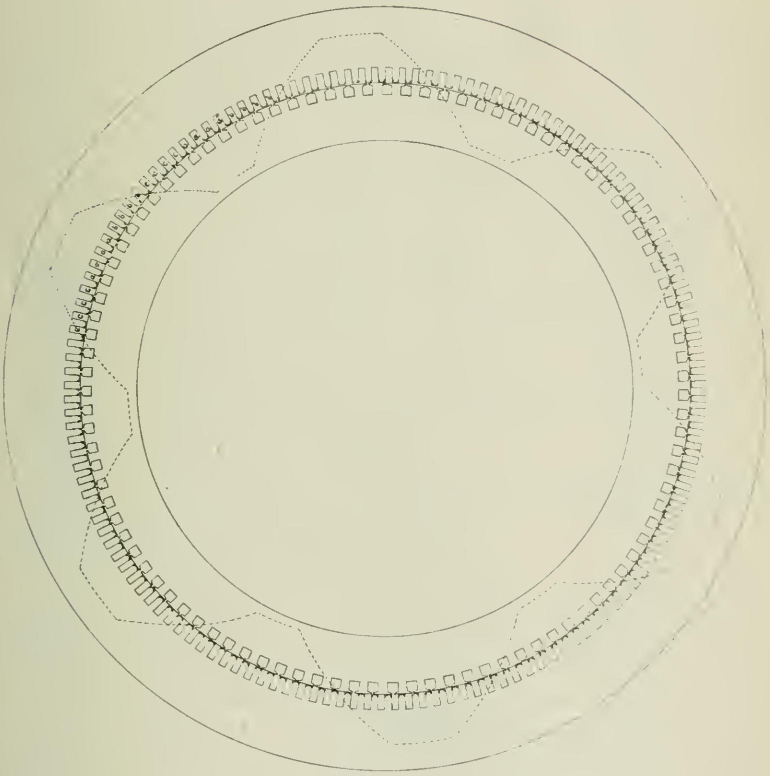


FIG. 1.

Poles	12
Primary connection	delta.
“ circuits per phase	1
Number of primary slots	144
Dimensions “ “	·36 x 1·6 in.
“ “ conductors	1 x ·6 “
Primary conductors per slot	4
Secondary connection	sq. cage.

Secondary slots	99
Width of secondary slots	·55 in.
Total depth of secondary slots	·58 "
Secondary conductors per slot	1

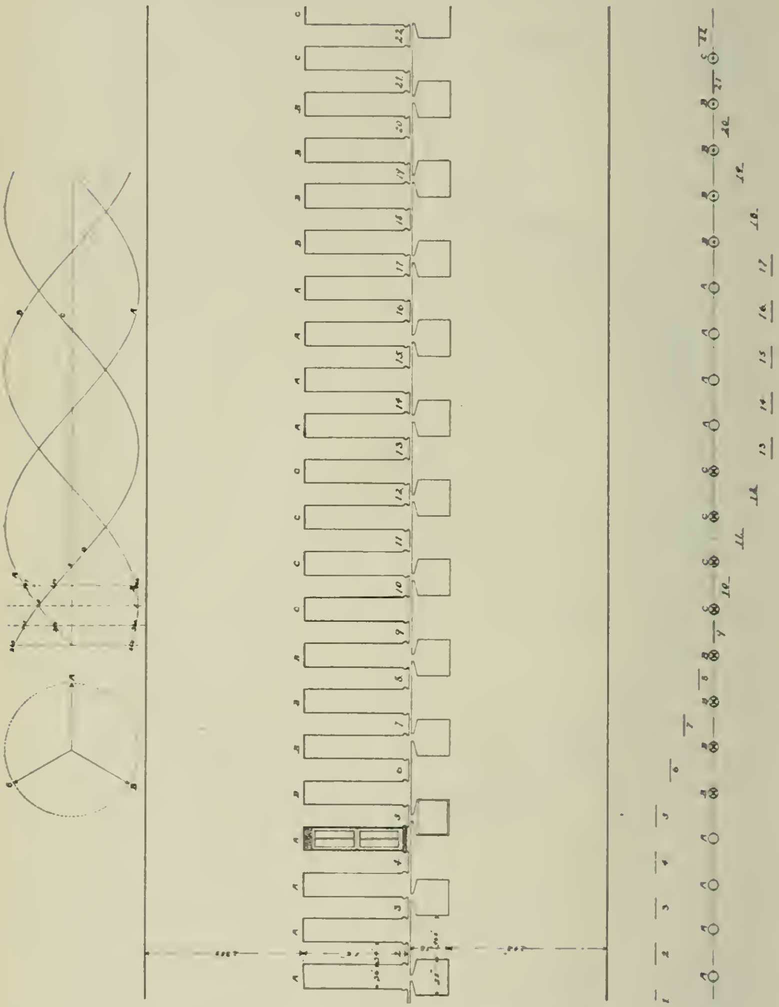


FIG. 2.

The magnetic circuit or flux-carrying parts of this motor are drawn to scale in *Fig. 1.* Since there are three phases and twelve poles, there are four slots per phase per pole, the phases being grouped as indicated by the letters *aaaa*, *bbbb*, *cccc*, *aaaa*, etc., in *Fig. 1*. The magnetic field produced by the three currents at a particular instant in the operation of the motor is shown graphically in *Fig. 1* by a dotted line. The bore of the primary is taken as the axis of abscissas, and since this is a circle the resulting curve of flux distribution is a little distorted. It will be noted that six poles are positive and six negative, a total of twelve.

Distribution of Magnetism.—In *Fig. 2* an enlarged view of a section of this magnetic circuit is shown. For convenience the diagram is developed so that the primary bore becomes a straight line. The slots are lettered as before for the separate phases, and in one slot of both primary and secondary the arrangement of conductors is shown.

In the upper part of *Fig. 2* is given the conventional sine-wave diagram for a three-phase circuit. Selecting the instant when the current *A* is zero, currents *B* and *C* are ·866 of their maximum. If the reluctance of the air-gap be very large as compared with that of the iron part of the circuit, so that the total M.M.F. of these currents acts at the air-gap, this M.M.F., as found at each of the twenty-two teeth shown in the figure, may be readily plotted. Such a construction is found at the lower part of *Fig. 2*. The conventional signs between the positions of the teeth in this figure show the directions of the currents *B* and *C*.

It is obvious that the phase relations of the sine curves give no indication as to the manner in which the currents are connected to the machine. In this instance the scheme of connection is such that, starting at the left of the figure and moving to the right, each new group of slots reached is carrying such a current as was carried by the preceding group a little earlier in time. The resultant effect is similar to that of a motion from right to left of both currents and magnetism.

Method of Plotting.—In the case chosen for *Fig. 2*, where one current is zero and the other two are equal, it is a very simple matter to compute the M.M.F. acting through each tooth since all the flux paths are symmetrical. It is not always so obvious, however, how this should be done, and it is perhaps desirable to show that the method followed is a proper one for any current distribution.

It will be assumed that in any magnetic circuit under consideration the conditions are approximately as follows:

(1) The magnetic circuits are formed in two concentric rings of laminated metal, as in *Fig. 2*.

(2) The total reluctance of any circuit is located in the air-gap between the rings.

(3) All magnetic circuits are parallel to the paper.

(4) The magnetic fields are set up by currents in conductors which lie in the slots of the outer ring, and which are perpendicular to the plane of the paper.

(5) For each current in a single slot there are present similar currents at equidistant points around the circumference, the total number in each case being equal to the number of magnetic circuits.

A general case fulfilling these conditions is illustrated in *Fig. 3*. In this figure the current in conductors A_1, A_2, A_3 and A_4 is 200 amperes; that in conductors B_1, B_2, B_3 and B_4 is 100 amperes; and in conductors C_1, C_2, C_3 and C_4 is 50 amperes. It is required to find the manner in which the flux is distributed around the air-gap in this figure.

Since the reluctance of the iron is assumed to be zero, that of the air is the only item limiting the flux established by a given M.M.F. As the permeability of air is unity, a given change in M.M.F. will always produce the same change in the flux present, no matter what may be the flux density. Under these circumstances we may make use of the principle of "superposition;" that is, the field due to any combination of currents is equal to the geometrical sum of the fields which would be produced by each current taken separately. Since all fields are radial at the air-gap in the present instance the geometrical sum is also the algebraic sum.

Selecting the four conductors A_1, A_2, A_3, A_4, it is evident that, taken alone, equal fields would surround each, and that these fields would lie in the quadrants formed by the lines $A'A'$ and $A''A''$. Since the flux in any case must cross the air-gap twice, it will encounter an equal reluctance by any path. The flux density is therefore uniform over the entire circumference, and is such as would be produced by 100 ampere turns of M.M.F. applied at each point of the air-gap. Let us call flux leaving the inner ring positive, and flux entering the inner ring negative. Then in *Fig. 3* there are due to currents in the *A* conductors only:

From	A_1 to A_2	— 100 A. T.
"	A_2 to A_3	+ 100 A. T.
"	A_3 to A_4	— 100 A. T.
"	A_4 to A_1	+ 100 A. T.

Similar reasoning will show that with current in the *B* conductors only, we should have:

From	B_1 to B_2	— 50 A. T.
"	B_2 to B_3	+ 50 A. T.
"	B_3 to B_4	— 50 A. T.
"	B_4 to B_1	+ 50 A. T.

or with only the *C* conductors carrying current the M.M.F. at various points would be:

From	C_1 to C_2	— 25 A. T.
"	C_2 to C_3	+ 25 A. T.
"	C_3 to C_4	— 25 A. T.
"	C_4 to C_1	+ 25 A. T.

When all the currents are present simultaneously an algebraic addition gives:

From	A_1 to B_1	— 25 A. T.
"	B_1 to C_1	— 125 A. T.
"	C_1 to A_2	— 175 A. T.
"	A_2 to B_2	+ 25 A. T.
"	B_2 to C_2	+ 125 A. T.
"	C_2 to A_3	+ 175 A. T.

and so on.

The dotted lines with arrow-heads, which are drawn in *Fig. 3*, indicate graphically this air-gap distribution, one line crossing each 15° for each 25 ampere turns. No attempt has been made to show the exact distribution in the iron. The following notes may be made upon this figure:

(1) No flux circuit is formed that does not include one of the *A* conductors, these carrying a larger current than the others.

(2) Some flux travels by a route that includes all the conductors, *A*, *B*, *C*, of one group.

(3) The flux does not divide symmetrically between one group, A_1, B_1, C_1, and the adjacent groups, as A_2, B_2, C_2, but the flux belonging to one group extends almost over to the conductor *C* of the next group.

It should, of course, be borne in mind that *Fig. 3* represents a very special case of flux distribution, and particularly that the conditions practically preclude leakage.

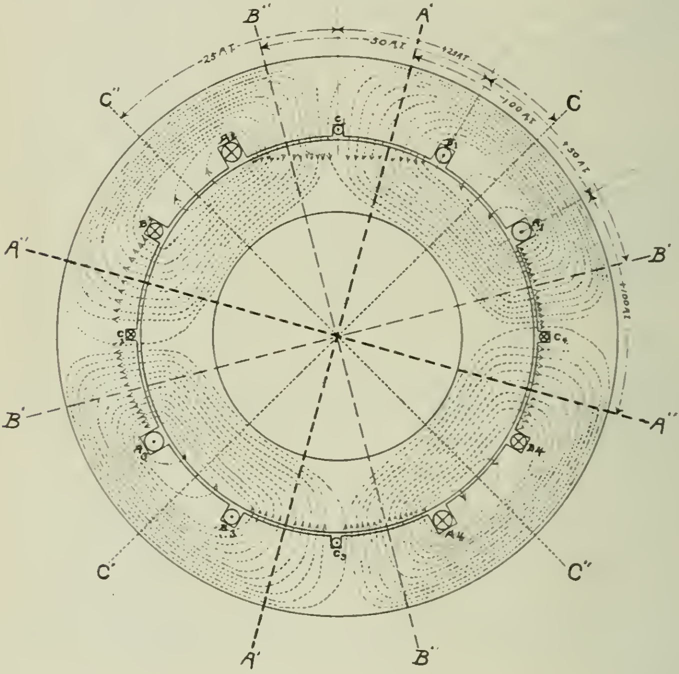


Fig. 3.

Actual Distribution in Motor.—In the actual motor the reluctance of the iron part of the magnetic circuit is not zero, but except for the teeth such reluctance is relatively small. It may be assumed, without great error, that taking the teeth and air-gap together, nearly all of the reluctance of any magnetic path is contained therein. The flux, or M.M.F., at each tooth may then be determined by the method of the preceding paragraph without great labor. The only error of any importance in such a determination lies in the assumption that the flux is proportional to the M.M.F. The magnitude of this error will be estimated later.

In order to make the problem as concrete as possible, it is assumed that each conductor will carry a sine-wave of current, having an effective value of 45 amperes. The results obtained, being proportional to the current, will serve equally well for any current value. A current of 45 amperes was taken because, as nearly as could be estimated from experimental data on other motors, 45 amperes was the most probable value for the magnetizing current of this motor.

It is assumed that the secondary bars are present, but are unconnected at the ends, so that no secondary current may flow. The flux distribution will be determined for intervals of 15°, measured on sine curve *A*, *Fig. 2*, and starting with the phase angle of *A* equal to zero. The successive currents in conductors lying in the *A* slots will, therefore, be, 0, ·259, ·5, ·707, ·866, ·966, ·1, ·966, etc., where the maximum value is unity and the interval is 15°. With four conductors per slot, each carrying 45 effective amperes, the total current per slot is 180 effective, or 254 maximum, amperes, and the various momentary currents are as follows:

PHASE ANGLE OF PHASE *A*	CURRENT IN PHASE. *A*	*B*	*C*
0°	0	220	220
15°	65	245	180
30°	127	254	127
45°	180	245	65
60°	220	220	0
75°	245	180	65
90°	254	127	127

The net M.M.F., applied to the teeth and air gap by these currents, is set down in the table on the following page for the teeth positions, shown in *Fig. 2.*

It may be noticed from this table that there is a regular progression, from tooth to tooth, of the zero line of flux. The position of this line is dotted across the table.

The point of maximum flux moves in the same direction, but not regularly, and is noted on the table by a jagged line of dots. A line made up of dashes, and dividing each flux group into equal parts, is also drawn across the table. This line is straight, and indicates a uniform progression of the

Ampere Turns at Tooth No.	Phase Angle of Phase "A."												
	0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
1.	880	982	1016	982	880	720	508	262	0	-262	-508	-720	-880
2.	880	917	889	802	660	475	254	17	-220	-442	-635	-785	-880
3.	880	851	762	622	440	229	0	-229	-440	-622	-762	-851	-880
4.	880	785	635	442	220	-17	-254	-475	-660	-802	-889	-917	-880
5.	880	720	508	262	0	-262	-508	-720	-880	-982	-1016	-982	-880
6.	660	475	254	17	-220	-442	-635	-785	-880	-917	-889	-802	-660
7.	440	229	0	-229	-440	-622	-762	-851	-880	-851	-762	-622	-440
8.	220	-17	-254	-475	-660	-802	-889	-917	-880	-785	-635	-442	-220
9.	0	-262	-508	-720	-880	-982	-1016	-982	-880	-720	-508	-262	0
10.	-220	-442	-635	-785	-880	-917	-889	-802	-660	-475	-254	-17	220
11.	-440	-622	-762	-851	-880	-851	-762	-622	-440	-229	0	229	440
12.	-660	-802	-889	-917	-880	-785	-635	-442	-220	17	254	475	660
13.	-880	-982	-1016	-982	-880	-720	-508	-262	0	262	508	720	880
14.	-880	-917	-889	-802	-660	-475	-254	-17	220	442	635	785	880
15.	-880	-851	-762	-622	-440	-229	0	229	440	622	762	851	880
16.	-880	-785	-635	-442	-220	17	254	475	660	802	889	917	880
17.	-880	-720	-508	-262	0	262	508	720	880	982	1016	982	880
18.	-660	-475	-254	-17	220	442	635	785	880	917	889	802	660
19.	-440	-229	0	229	440	622	762	851	880	851	762	622	440
20.	-220	17	254	475	660	802	889	917	880	785	635	442	220
21.	0	262	508	720	880	982	1016	982	880	720	508	262	0
22.	220	442	635	785	880	917	889	802	660	475	254	17	-220
23.	440	622	762	851	880	851	762	622	440	229	0	-229	-440
24	660	802	889	917	880	785	635	442	220	-17	-254	-475	-660

flux. The total quantity of flux varies somewhat, and this variation is indicated by the numbers 7040, 7104, 7112, 7104, 7040, etc. These numbers are computed upon the assumption that the flux and M.M.F. are proportional, and they are more nearly equal to each other than this assumption is to the truth, so that for all practical purposes the following conclusions may be regarded as reached for this motor:

(1) The total quantity of flux is constant.

(2) The points of zero flux move around the circumference at a uniform velocity.

(3) The points of mid-flux move around the circumference with a uniform velocity.

(4) The points of maximum flux move around the circumference, but not with a uniform velocity.

The points of maximum flux move with twice the velocity of the points of zero flux, but are moving only half of the time, so that the net rate of progression is the same for either.

From facts Nos. 1, 2 and 3, we may state the following —which is true at least for this particular motor.

The effect of the changing magnetism upon the primary conductors is practically the same as would be produced if the primary were on open circuit and the secondary were replaced by a rotating field having twelve poles, each pole having a flux distribution varying from a maximum at its center to zero at a point midway between poles.

That is to say, there has been produced a *changing field similar to, and practically the same as, a rotating field.*

Graphical Construction.—In *Fig. 4* the flux distribution, as indicated by the accompanying table, is shown graphically. The dotted parallelograms, marked 1 to 22, represent the position of the teeth of *Fig. 2*. The short horizontal lines across these indicate by their distances from the axis, the successive M.M.F.'s acting at each tooth, and the dotted lines joining these horizontals show the distribution over a portion of the air gap, for eight different instants, $\frac{1}{24}$ of a cycle apart.

At the lower part of *Fig. 4* are drawn curves showing the magnetic cycles through which typical teeth, Nos. 9, 10 and 11, must continually pass. These values were determined from the upper figure. There are sine curves, as was to have been expected. They show that the limits of

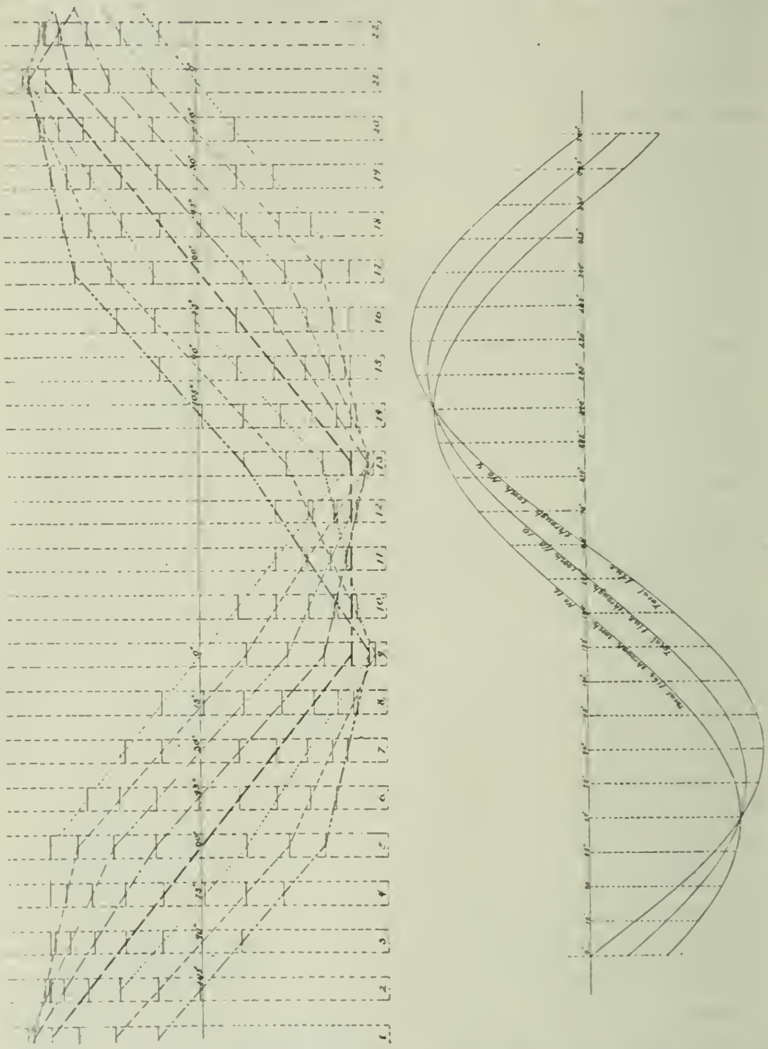


FIG. 4.

magnetic density, and the hysteresis losses, are not the same in different teeth. The three sine-waves shown represent, however, the entire variation in the machine under discussion.

The counter E.M.F. induced in a single conductor of the primary circuit should, under the assumed conditions, be a sine-wave. It is of interest, however, to derive this from the determined fluctuations of the field, and to determine independently the phase and quantity relationships existing between the E.M.F.'s induced in conductors lying in four adjacent slots of a single-phase group.

This was done in the following manner: Referring to *Fig. 2* and to the table of M.M.F. distribution, quantities proportional to the flux actually surrounding the slot between teeth Nos. 13 and 14 were set down for phase angles of phase A, of 0°, 15°, 30°. . . . . . 180°. Since these values occur $\frac{1}{24}$ of a cycle apart, the difference between two successive values is proportional to the average E.M.F. induced in a conductor lying in such a slot during that part of a cycle.

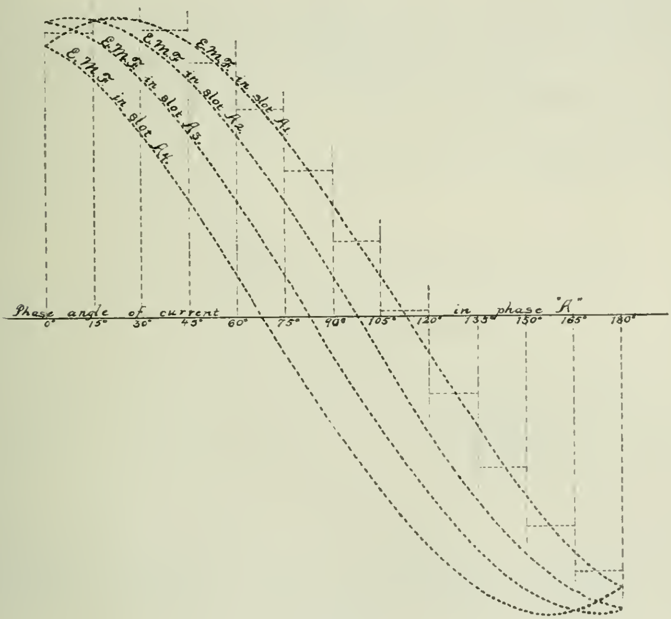


FIG. 5.

These differences were carefully determined, and in *Fig. 5* they are plotted as horizontal lines, 15° in length, and at appropriate intervals. The curve *A* was sketched through these horizontals in such a manner that each horizontal should be an average ordinate for that part of the curve lying between the same vertical lines. Curves A_2, A_3 and A_4, were plotted in a similar manner, though their construction lines are not given in *Fig. 4.*

As nearly as could be determined by this graphical method all the curves are sine curves, and are equal. This, of course, was to be expected, and serves as a check upon the numerical work.

Total Flux Present.—Since the primary resistance of the motor is low, the counter E.M.F., with a magnetizing current of 45 amperes per conductor, is almost exactly the same as that which is impressed, or is 220 volts, effective pressure. Since each phase has an equal number of conductors in corresponding slots of each group, it follows that the E.M.F. induced in the conductors of one slot of each group must bear to 220 volts the same relation that the E.M.F. curve *A*, for example, bears to the sum of curves A_1, A_2, A_3, A_4.

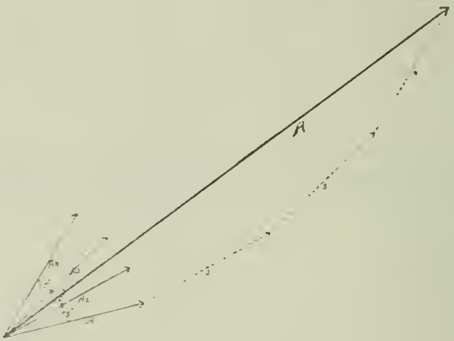


FIG. 6.

But the E.M.F.'s of *Fig. 5* are not in phase, and their sum is less than four times either. In other words, there are times when the E.M.F. generated in certain conductors of one phase is opposed to that generated in others of the same phase. There is then a *differential action*, as is the case in many A. C. dynamos.

Obviously the magnitude of such a differential action will depend upon the space occupied along the primary bore, by a group of conductors belonging to a single phase, or it will be greater as the number of slots per phase and pole is increased. In this case the situation is illustrated in *Fig. 6*, where A_1, A_2, A_3, and A_4, represent the E.M.F.'s in each set of slots, and A represents the E.M.F.'s of the entire phase. Each component factor must be 51·8 average volts, if the sum is to be 198 average, or 220 effective volts, or there are lost 9·2 average volts, or 4·65 per cent. of the total pressure. The actual flux per pole must, therefore, be 4·65 per cent. larger than if differential action were absent.

There are 192 conductors in series in each phase, and the magnetism is equivalent to a rotating field making 250 revolutions per minute. To generate 198 average volts, the flux must be as follows:

$$\Phi \times 192 \times \frac{250}{60} \times 12 = 19800000000 \times 1{\cdot}046$$

or,

$$\Phi \times 2{,}156{,}000 \text{ maxwells per pole;}$$

or with the assumed magnetizing current of 45 amperes, one ampere turn applied at a tooth sends through it 304 maxwells. In this discussion it has so far been assumed that no flux surrounds primary conductors locally. The total flux passing through each primary tooth and the corresponding flux density are set down in the succeeding tables, the current values and flux distribution being as previously determined:

FLUX DENSITIES IN TEETH.

Tooth No.	Phase Angle of Phase A.			
	0°	15°	30°	45°
6	62800	45200	24100	1600
7	41800	21700	0	21700
8	20800	1600	24100	45200
9	0	24800	48400	68500
10	20800	42000	60400	74600
11	41800	59100	72200	80800
12	62800	76200	84500	87000
13	83600	93200	96500	93200
14	83600	87000	84500	76200
15	83600	80800	72200	59100

Tooth No.	Phase Angle of Phase A.			
	0°	15°	30°	45°
16	83600	74600	60400	42000
17	83600	68500	48400	24800
18	62800	45200	24100	1600
19	41800	21700	0	21700
20	20809	1600	24100	45200
21	0	24800	48400	68500

Flux at Teeth.

Tooth No.	Phase Angle of Phase A.			
	0°	15°	30°	45°
6	200600	144400	77200	5200
7	133700	69600	0	69600
8	66800	5200	77200	144400
9	0	79600	154400	218800
10	66800	134400	193000	238600
11	133700	189000	231600	258700
12	200600	243800	270200	278700
13	267500	298500	308800	298500
14	267500	278700	270200	243800
15	267500	258700	231600	189000
16	267500	238600	193000	134400
17	267500	218800	154400	79600
18	200600	144400	77200	5200
19	133700	69600	0	69600
20	66800	5200	77200	144400
21	0	79600	154400	218800

Flux Distribution in Primary Core.—In order to determine the effect of the reluctance actually present in the iron core, and to estimate the error that is involved in neglecting it, we will select the instant when the phase angle of phase *A* is 30°, and will make use of the quantities and densities found in the preceding tables for that condition. This particular instant is chosen for study because at that time the greatest density of flux is found in a single tooth of the primary, and the total quantity of flux is a maximum. The values of flux given in the tables are not to be considered as final, but may be taken as first approximations, subject to later corrections should further study prove such corrections necessary.

At the instant chosen the flux is zero in tooth No. 7, and is most dense at teeth Nos. 1 and 13. In *Fig. 7* is given a drawing of the primary part of the magnetic circuit which includes half of teeth Nos. 1 and 13. From the fact that the flux distribution in the primary teeth is symmetrical about tooth No. 7, it follows that, neglecting any local or leakage flux, the distribution in the primary core will also be symmetrical, or half the flux of tooth No. 1 goes to tooth No. 13; flux from tooth No. 2 goes to tooth No. 12; No. 3 to No. 11, and so on.

The probable path of the flux in each case is indicated by dotted lines in the figure. The position of these lines was determined by a method of trial and error. First the lines were sketched in as it was thought they should be drawn. Then equipotential lines were drawn crossing these at right-angles. Taking one section bounded by two equipotential lines, the flux of each path should occupy a width proportional to its amount and to the distance between the two equipotentials at that point. The new or corrected positions of the boundary lines of the flux paths were thus located, new equipotential lines sketched in, and a second computation made. This process was repeated until the corrections became negligible. The flux densities, in kilomaxwells per square inch, are marked on *Fig.* 7 at a number of points.

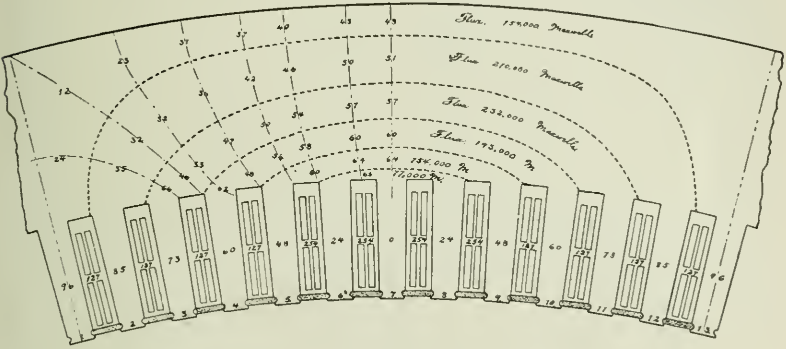


FIG. 7.

The flux density and distribution in the primary core being thus determined with fair accuracy, a curve showing the relation between such densities and the M.M.F. per inch of path required to produce them was constructed. This curve (*Fig. 8*) was taken from a curve given by Parshall and

Hobart as the magnetization curve for laminations of "electric steel" of good average quality. Using this curve, careful determinations were made for the M.M.F.'s per inch of path, at equal intervals along each path in the core. The final average of these results is given below. In this and similar tables, path No. 1 means the path between teeth Nos. 1 and 13; path No. 2 is between teeth Nos. 2 and 12, etc.:

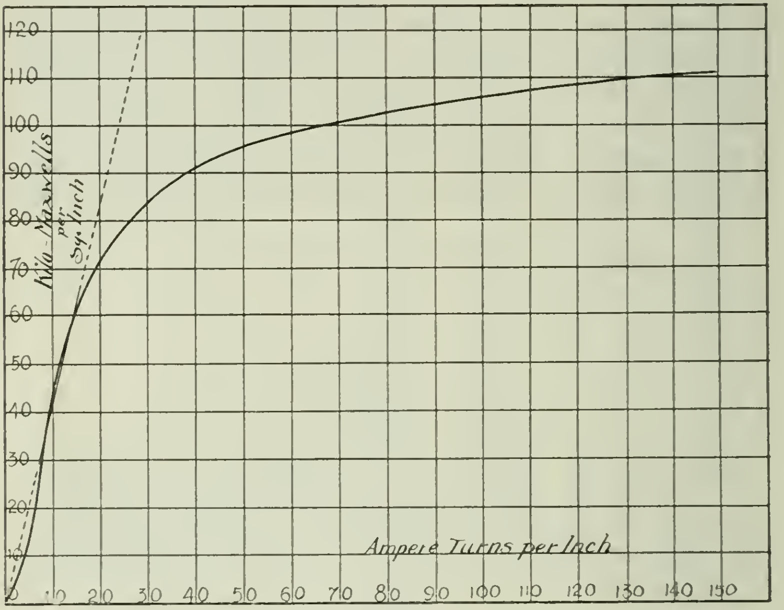


Fig. 8.

Path No.	Length in Inches.	Average Ampere Turns Per Inch.	Ampere Turns in Core.
1	13·3	9·1	121
2	10·35	9·9	102
3	7·25	10·8	78
4	5·1	11·6	59
5	3	12	36
6	2·5	10	25

The flux densities in the primary teeth are in general higher than in the core. The complete path in any case includes two teeth or a total lengh of 3·2 inches. The section of the tooth is not uniform, being smaller at the face than at the root. Also considerable flux leaves the tooth before reaching the face, and takes a longer route through the air gap. One of these facts tends to counterbalance the other. It will be quite sufficiently accurate to make use of the average section and of the total length.

Again, making use of the curve in *Fig. 8*, the M.M.F. used up in the different teeth was determined, as follows:

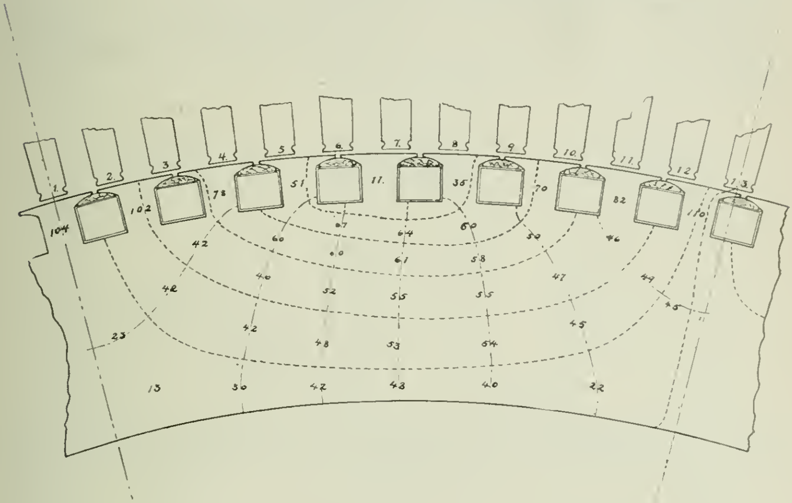


FIG. 9.

AMPERE TURNS USED UP IN PRIMARY TEETH.

Path No.	Average Ampere Turns Per Inch.	Ampere Turns in Teeth.
1	52	166
2	31	100
3	21	67
4	14	45
5	11	35
6	7	22

Flux Distribution in Secondary Iron.—In the discussion of the flux distribution of the primary, it was tacitly assumed that the question of secondary reluctance did not affect such distribution. This is not absolutely true, as an inspection of *Fig. 9* will indicate. In *Fig. 9* we have a drawing of the secondary part of the same magnetic circuit that was in part shown in *Fig. 7*. It may be noted that the symmetrical distribution of the primary is not repeated in the secondary. This is, of course, due to the differing numbers of teeth in primary and secondary. This difference does not, however, have as much effect as might at first sight be supposed, since the tops of the secondary teeth nearly join, so that the secondary presents a nearly continuous magnetic surface.

In order to estimate as nearly as possible the air gap distribution to the tops of the secondary teeth, the large scale drawings of *Figs. 10* and *11* were constructed, and curves of flux density were made for each primary tooth of these figures. To determine these curves the method of Professor Goldsborough (Trans. Am. Inst. Elect. Engrs., 1898) was employed. The wavy dotted line in *Figs. 10* and *11* is the sum of the separate density curves, and indicates graphically the actual flux density over the surface of the secondary.

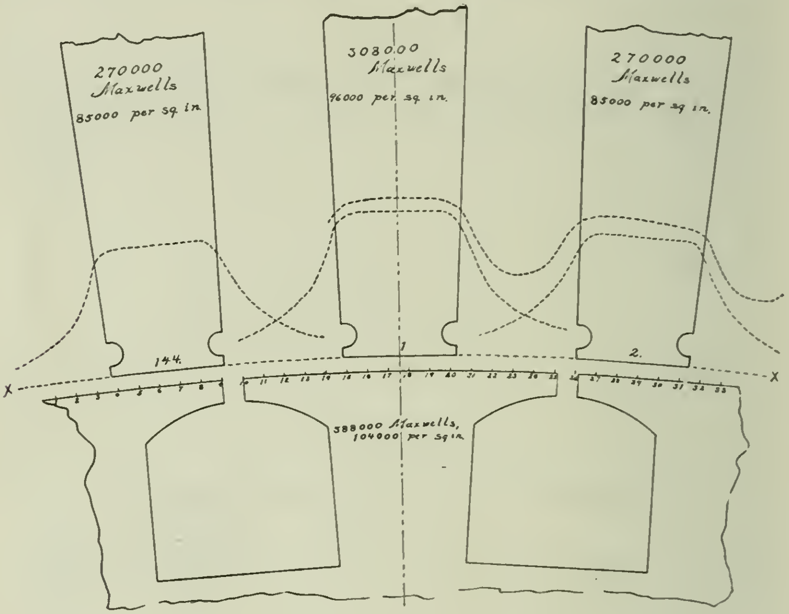


FIG. 10.

In estimating the quantity of flux entering a given secondary tooth from a particular primary tooth it was assumed that the primary tooth supplied that part of the total wave lying between two points of minimum flux on either side of the tooth. This area, and the part of the area lying over the secondary tooth in question, were measured, and the ratio of one to the other taken to be the ratio of the total flux through the primary tooth, to the part of it which entered the given secondary.

M.M.F. Used up in Air Gap.—The method used for the determination of the M.M.F. expended in sending the flux across the air gap depends upon the magnetic density curves of *Figs. 10* and *11*. The accuracy of this determination depends therefore upon the accuracy of those curves. The method may be illustrated by applying it to path No. 1. Taking the flux wave belonging to tooth No. 1, *Fig. 10*, the ratio of its maximum ordinate to its average ordinate is 1·23. That is to say, if there were no teeth or slots, and flux were distributed uniformly over the entire air gap at the average rate at which it occurs in the neighborhood

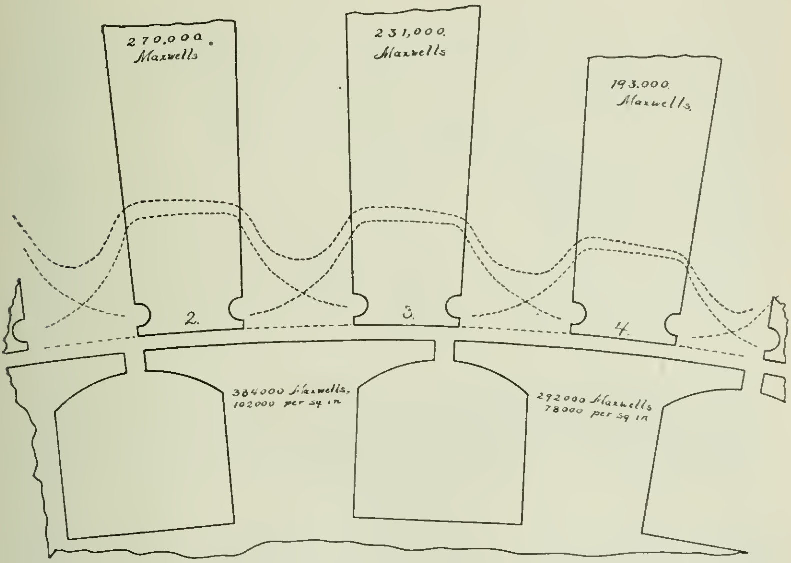

270,000 Maxwells
231,000 Maxwells
193,000 Maxwells
2.
3.
4.
384000 Maxwells, 102000 per sq in
292000 Maxwells 78000 per sq in

FIG. 11.

of tooth No. 1, the density would be less than the present maximum density in the ratio of 1· to 1·23.

The M.M.F. which would, in such an event, be necessary at the air gap is $\text{M.M.F.} = \cdot 045 \times \cdot 313 \times 51{,}300\cdot = 723$ ampere turns. Where ·045 is the length of the air-gap, ·313 is the number of ampere turns required to set up one maxwell per square inch, through a distance of 1 inch in air, and 51,300 is the average density under tooth No. 1, and half of each of the adjacent slots.

Under the actual conditions we find a flux density of $51{,}300 \times 1\cdot 23 = 63{,}200$ maxwells per square inch under the center of tooth No. 1. The M.M.F. required to set it up is $\text{M.M.F.} = \cdot 045 \times 313 \times 63{,}200 = 890$ ampere turns. Considering all points within half an inch of the face of primary tooth No. 1 to be at the same magnetic potential, and all points on the face of a given secondary tooth to have a constant potential, it follows that the M.M.F. by any flux path across the air gap, from primary tooth No. 1 to the secondary tooth immediately under it, is 890 ampere turns. For the complete path No. 1, which crosses the air gap at teeth Nos. 1 and 13, the M.M.F. used up in the air is therefore twice 890, or 1780 ampere turns.

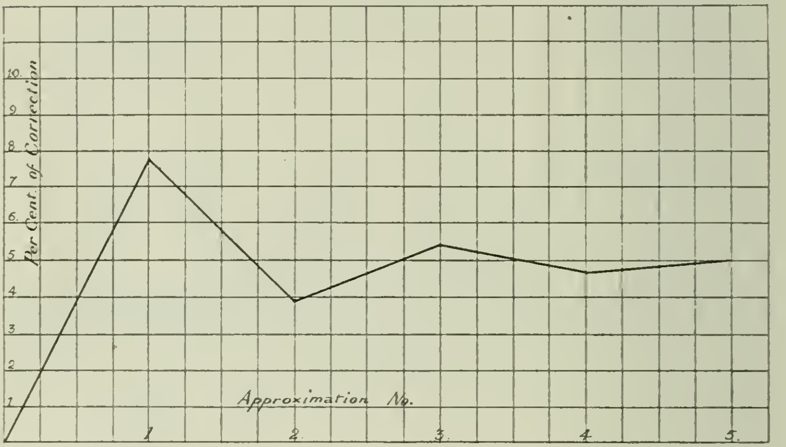


FIG. 12.

The same method applied to other portions of the air gap gives the M.M.F. needed for the other routes, as set down in the following table:

M.M.F. USED IN DOUBLE AIR GAP.

Path No.	Maximum Density in Air.	Ampere Turns for Double Air Gap.
1	63,000	1,780
2	55,500	1,560
3	47,500	1,340
4	40,000	1,130
5	31,700	890
6	15,900	450

For the secondary teeth and core the method is the same as was used in the primary, and the results follow.

M.M.F. USED IN SECONDARY IRON.

Path No.	Ampere Turns in Teeth.	Ampere Turns in Core.	Ampere Turns Total.
1	103	86	189
2	84	80	164
3	36	67	105
4	20	57	77
5	12	55	47
6	7	17	24

General Summary.—The final addition of the M.M.F.'s used up in various parts of the magnetic circuit, and for various paths, is given in the succeeding tables. A comparison is made in the second table between the magnetomotive forces used near the air gap and in the cores, and a comparison is also made between the total M.M.F. as now computed and the original estimate, which was made on the basis of 45 effective amperes per primary conductor:

TOTAL MAGNETOMOTIVE FORCE.

Path No.	A. T. in Cores.	A. T. in Teeth.	A. T. in Air Gap.	Total A. T.
1	186	269	1,780	2,235
2	172	186	1,560	1,918
3	151	103	1,340	1,594
4	126	65	1,130	1,321
5	83	47	890	1,020
6	43	26	450	519

COMPARISON.

Path No.	A. T. Cores.	A. T. in Teeth Plus Gap.	Total. A. T.	Previously Estimated.
1	186	2,049	2,235	2,032
2	172	1,746	1,918	1,778
3	151	1,443	1,594	1,524
4	126	1,195	1,321	1,270
5	83	937	1,020	1,016
6	43	476	519	508

The results of the computations are in remarkably close agreement with those which were estimated for a magnetizing current of 45 amperes, that being the best value that could be obtained from the test reports of a line of similar motors. It seems probable that the variation between different individual motors built from the same drawings would be as much as the difference between these results and the average of experiments.

Since no account has so far been taken of leakage or of the small amount of flux present in the slots, ventilating spaces, etc., the results of the computation show a slightly larger amount of flux in the iron, and therefore call for a larger magnetizing force than would be actually needed. A correction for this would bring the estimated and computed values into still closer agreement.

Effect of Correcting Certain Approximations.—The particular value of such a study as the preceding lies in the possibility that the results obtained may assist one in forming an idea of the reasonableness of certain customary approximations, and of the places where approximations may be freely used, and where only with great caution. We are now in a position to examine the effect upon the preceding study of various minor corrections. The propositions which have been assumed, tacitly or otherwise, are:

(1) All the reluctance of the magnetic circuits is contained in the teeth and air gap.

(2) All parts of the magnetic circuits have a constant permeability.

(3) No flux surrounds individual conductors, or conductor groups, locally.

(4) The flux is entirely confined to iron, except at the air gap.

(5) The conditions of the moment chosen are constant.

None of these statements are strictly true. It is desired to determine the probable error involved in taking them as accurate.

(1) From the accompanying table, it is seen that the reluctance of any magnetic circuit is principally that of the air gap and teeth. The per cent. of total reluctance found in that part of the circuit is as follows:

	Per Cent.
Path No. 1	92
Path No. 2	91·3
Path No. 3	90·7
Path No. 4	90·5
Path No. 5	91·7
Path No. 6	91.8
Average	91·3

The error in distribution, due to the inaccuracy of assumption No. 1, cannot therefore be greater than one due to a total change in the reluctance of about 10 per cent. As shown above, this change is practically the same by any path. The alteration in the *distribution* is therefore entirely negligible.

(2) The permeability of the air gap is of course constant. The permeability of the iron is nearly constant within a limited range, but is far from constant over a wider one.

Assumption No. 2 may be quite incorrect in some instances and negligible in others. In *Fig. 8*, a straight line is drawn through the origin in such a way as to become an average of the magnetization curve for a portion of its length. If the magnetization curve and the straight line coincided, it would mean that flux density in the iron was proportional to the magnetomotive force applied to it. For any given density, the error involved in assuming the above to be true, is indicated by the horizontal distance between the two curves. It may be noted that the two curves practically coincide between the flux densities of 25,000 and 65,000 maxwells per square inch.

In referring to *Figs. 7* and *9* it is seen that, with trifling exceptions, the flux densities in the primary and secondary cores lie within those limits. The primary and secondary teeth belonging to the three outer paths carry flux at a higher density than 65,000. The diminution in the actual flux carried by these three paths may be noted by a trial and error method, first applying a correction to the original value, then determining a correction for that result, and so on. The process is given in full for path No. 1, and the results are given for paths Nos. 2 and 3.

PATH No. 1.

FIRST APPROXIMATION.

Density in primary teeth	96,000
Ampere turns per inch for this density	52
Ampere turns as assumed (from straight line)	23
Difference per inch	29
Difference for path including two teeth	93
Density in secondary teeth	104,000 and 110,000
Average ampere turns per inch	115
Ampere turns as assumed	26
Difference per inch	89
Difference for path	80

Total loss in flux owing to decreased permeability of high-density teeth, equivalent to a loss in path No. 1 of 173 ampere turns, or 7·75 per cent. of the total.

SECOND APPROXIMATION.

Density in primary teeth (from preceding)	88,600
Density in secondary teeth " "	96,900 and 101,500
Ampere turns per inch, primary	36
Ampere turns per inch, as assumed	21
Difference per inch	15
Difference for path	48
Ampere turns per inch, secondary	66
Ampere turns as assumed	24
Difference per inch	42
Difference for path	38

Total loss in flux equivalent to a loss of 86 ampere turns, or 3·9 per cent. of the total.

THIRD APPROXIMATION.

Density in primary teeth (from preceding)	92,300
Density in secondary teeth " "	100,000 and 105,000
Ampere turns per inch, primary	444

Ampere turns per inch, as assumed	23
Difference per inch	21
Difference for path	67
Ampere turns per inch, secondary	85
Ampere turns, as assumed	25
Difference per inch	60
Difference for path	54

Total loss in flux, equivalent to a loss of 5·4 per cent. of the total, or to 121 ampere turns.

FOURTH APPROXIMATION.

Density in primary teeth (from preceding)	91,000
Density in secondary teeth	98,300 and 104,000
Ampere turns per inch, primary	40
Ampere turns per inch, as assumed	22
Difference per inch	18
Difference for path	58
Ampere turns per inch, secondary	75
Ampere turns, as assumed	25
Difference per inch	50
Difference for path	45

Total loss in flux, equivalent to a loss of 4·6 per cent. of the total, or to 103 ampere turns.

FIFTH APPROXIMATION.

Density in primary teeth (from preceding)	91,500
Density in secondary teeth	99,000 and 105,000
Ampere turns per inch, primary	41
Ampere turns, as assumed	22
Difference per inch	19
Difference for path	61
Ampere turns per inch, secondary	80
Ampere turns, as assumed	25
Difference per inch	55
Difference for path	50

Total loss in flux, equivalent to a loss of 5 per cent. of the total, or 111 ampere turns.

So many as five approximations are not necessary, except for illustration. The final value may usually be predicted closely enough after two or three approximations. The manner in which the final value is approached is indicated graphically in *Fig. 13*. The change due to each successive approximation is seen to be about half of the preceding change.

The immediate effect therefore of the low permeability of the high density teeth is to reduce the flux about as follows, the values for paths Nos. 2 and 3 being obtained as above:

	Per Cent.
Path No. 1	5
Path No. 2	4
Path No. 3	1

Such a change in the flux of these teeth would cause other slight changes which in turn would react upon these values, some increasing and some diminishing them. Except as hereinafter noted, variations of that character are negligible.

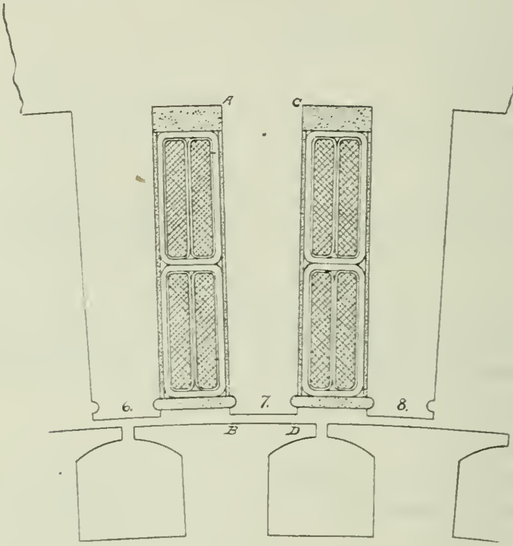


FIG. 13.

(3) *Leakage Flux.*—Under the specified conditions, *i. e.*, with the secondary on open circuit, the flux surrounding conductors locally, or surrounding groups of primary conductors, without entering the secondary, is an extremely small per cent. of the total amount. Under other conditions, however, such flux may become important, and it is desirable that its amount and distribution, with varying primary currents, should be carefully studied. The flux conditions that have heretofore been chosen for discussion are those when the phase angle of current in phase *A* is

30°. The currents in the slots of *Fig. 7* are there indicated, the larger currents being found in the central slots. Referring to *Fig. 13*, we find an enlarged drawing of teeth Nos. 6, 7 and 8, with the conductors lying between them.

Leakage flux may be divided into two parts.

(*a*) Complete flux path in non-magnetic media.

(*b*) Flux path partly in iron.

Flux as in (*a*) occurs along the total length of each primary conductor, and along the end connections as well. Flux as in (*b*) is found only for a conductor length equal to the net length of laminations parallel to the shaft.

To obtain a rough idea of the order of magnitude of class (*a*), neglecting end connections, we will assume flux paths coincident with insulation sheaths, as indicated in *Fig. 13*. A computation on this basis gives the following results:

Total flux per slot surrounding a single conductor only	64	maxwells
Total flux per slot surrounding a pair of conductors	134	"
Total flux per slot surrounding all four conductors	165	"
Total flux in insulation surrounding any single conductor of *Fig. 13*	248	"

These figures are not given as at all accurate, since the assumption on which they are based is a very rough one, but they serve to show that the leakage flux which occurs entirely in non-magnetic paths is quite unimportant as compared with the total.

Leakage Flux Partly in Iron.—This is a very complex matter, and one which is difficult of analysis. Obviously, so far as affects the primary alone—and we have as yet only considered primary E.M.F.'s—there will be no leakage flux unless a given tooth carries flux at the same time in two directions. Fsr example, in *Fig. 13*, with the conditions of the moment, and no leakage, flux travels downward through tooth No. 6, and upward through tooth No. 8; no flux existing in tooth No. 7.

With leakage, flux would travel downward in tooth No. 6, and upward partly in tooth No. 7, and partly in tooth No. 8, while some flux traveling upward in tooth No. 8 would return downward through tooth No. 7, completing a circuit without reaching tooth No. 6. That is, flux would be traveling upward on the left-hand side of tooth No. 7, and downward on its right-hand side. Such a flux would be most dense along either edge of this tooth, and would be set up by the difference between that part of the M.M.F. of the currents in slot 6–7 acting between the points *A* and *B*, *Fig. 13*, and the part of the M.M.F. of the currents in slot 7–8 acting between the same points.

From symmetry, neglecting any non-symmetry of the secondary, the M.M.F. 6–7, between *A* and *B* is equal to the M.M.F. 7–8 between *C* and *D*. The M.M.F. of 7–8 between *A* and *B* is less than this by the amount used up in forcing flux from *C* to *A* and from *B* to *D* through the iron, or by a trifling amount. This trifling difference acting along the tooth from *A* to *B* and across the air-gap at *B* would indeed set up a very slight flux, but not enough to be worth considering.

Leakage that may occur with respect to the secondary conductors, *i. e.*, that which may circle primary conductors, and not those of the secondary, is of more importance. Such flux may be set up along the ends of the primary teeth and across the intervening slots; or across the tops of the secondary teeth and between the ends of the secondary projections, or along the air gap. The amount of this leakage might be obtained if it were possible to compute the reluctance of the combined path and the M.M.F. applied to it. In so far as we may approximate to such determinations we may approximate to a determination of the leakage between primary and secondary.

For present purposes, with secondary conductors carrying no current, the M.M.F.'s are not large, and the distances through air are large, so that this flux is not very important. The matter of leakage with the motor running normally will be discussed later, though no very satisfactory method for predetermining this quantity seems to be possible, at least without an amount of labor disproportionate to the probable results.

(4) *Effect of Flux in the Slots.*—The amount of flux that crosses through the nonmagnetic substances lying in a slot

depends principally upon the degree to which the iron of the neighboring teeth is saturated. In the case of the present motor the teeth densities are rather moderate and a very small proportion of the flux crosses through any slot. For illustration we will compute the probable flux found on either side of primary tooth No. 1 and present in the ventilating and lamination spaces. We have:

Ampere turns per inch in tooth No. 1	52
Ampere turns per inch through slot therefore are not more than	52
Maxwells per square inch in slot not more than . .	166
Area for flux in slot	3·78 sq. in.
Area for flux in ventilation spaces, etc.	·73 "
Total area	4·51 "
Total flux, maxwells	750
Flux in tooth No. 1	308,000
Proportion of flux in neighborhood of tooth No. 1, but not in iron	·24 p. c.

This is the worst case for the primary. In the secondary the maximum tooth density was estimated at 110,000 maxwells per square inch. Making a similar computation for this case we find the following:

Ampere turns per inch	140
Corresponding flux density in air	450
Total area for this density	6·67 sq. in.
Total flux not in tooth	3,000
Proportion of flux in neighborhood of tooth but not in iron	·96 p. c.

(5) *Conditions of the Moment.*—At the moment chosen for investigation the flux per pole has the greatest possible value and the flux in a single tooth at the center of a pole is at maximum density. The approximations that have been made are therefore less close than at any other moment.

The only other item which may change is the position of the secondary structure. Since the primary and secondary are unsymmetrical and the number of secondary teeth is not a multiple of the number of poles, it follows that the conditions of the moment, as studied in *Figs.* 7 and 9, are not precisely those of any other magnetic circuit, even at this instant. The changes which may be produced by a shifting of the secondary are changes in secondary-tooth density.

The conditions of *Figs.* 7 and 9 probably represent a fair average, since they are favorable to a low density in the teeth at the left of the figures and to a high density in those at the right, both being for the same magnetic circuit.

Operation.—So far nothing has been said about the theory of the motor or of the principles of its operation. We have simply examined the behavior of the magnetic circuit of a particular machine when an appropriate polyphase E.M.F. was applied to it. It remains to note qualitatively the behavior of this motor when running, and then to discuss the performance of induction motors in general.

[*To be continued.*]

MONEY SAVED BY UNITED STATES GEOLOGICAL SURVEY MAP.

In its issue of May 21, 1903, the *Engineering News* has an interesting article on the very expensive construction of the Pittsburg, Carnegie and Western Railroad near Jewett, Ohio, in which the following paragraph occurs:

"Perhaps the most instructive location problem solved in this work was one involving the use of an atlas sheet of the United States Geological Survey with a contour interval of 20 feet. Before the issue of this particular atlas sheet the preliminary surveys and first location of the proposed line had been completed, and work was about to begin when a new resident engineer, Mr. T. H. Loomis, was appointed. Happening to be personally acquainted with the Government topographer, Mr. W. T. Griswold, who was then engaged in mapping this part of Ohio, Mr. Loomis secured from him a photograph of the contour map then almost finished. From this photographic copy Mr. Loomis projected a new location between stations 650 and 836, effecting thereby a saving of 2,200 feet in distance and 75° of curvature, besides eliminating 600 feet of tunnel. This change measured in dollars and cents resulted in reducing the first cost of that portion of the road by at least $85,000. Turning to the last annual report of Mr. Charles D. Wolcott, Director United States Geological Survey, we find that 1864 square miles of the State of Ohio have been mapped thus far, at a cost of $12,000; yet one small atlas sheet, covering some 220 square miles, has been the means of saving a sum more than seven times what it has cost to map the whole 1864 square miles. As a tribute to the accuracy of the Government topographer, Mr. Griswold, it may be well to add that when the railway engineers ran their profile levels along the paper-projected line, at no place did the actual elevation differ more than 16 feet from the elevation scaled off the contour map. To any engineer acquainted with the roughness of Eastern Ohio and with the approximate methods necessarily employed in Government topographical surveys of such vast areas, these figures speak forciby enough. And it is well that just such facts as these should become generally known, for there has been altogether too great an apathy in the past in furthering the work of the United States Geological Survey—a work that is destined to be of incalculable value to every citizen of the United States."

The Otis Elevator Company's Electric Elevator for Private Residences.

[*Being the Report of the Committee on Science and the Arts. Sub-Committee: T. C. Smith, Chairman; Francis Head, J. Logan Fitts, C. C. Heyl.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2221.] PHILADELPHIA, June 1, 1902.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the Otis Elevator Company's Electric Elevator for Private Residences, reports as follows:

This elevator is the subject of numerous patents, covering a long period of time, and which are interesting as showing the gradual growth and development of this apparatus through its various stages, each step having been made as the necessity for it arose.

When elevators are to be used in public buildings and where the traffic is of such amount as to warrant the placing of an attendant in charge of each machine, the question is comparatively a simple one, as a great deal can be left to the discretion of the operator and many operations can be performed or omitted at his judgment. In the case of a machine, however, intended to be operated by persons absolutely unskilled in the art, and with no one near at hand to rectify mistakes, it becomes a serious and complicated problem to provide means to meet and fill the requirements of the many different combinations that may arise. This has been admirably carried out in the apparatus under investigation.

The investigating committee had an interview with Mr. Ihlder, of the Otis Company, the inventor of many of the devices covered by the later patents, and received from him a full explanation of the working of the apparatus. They then examined one of these machines in operation in this city, going carefully over the apparatus itself and testing the operation of the car in all combinations which they could think of as likely to occur in practice. The particular apparatus examined was one in which direct current at 220 volts is supplied from the Edison Central Station both for operating the motor and working the controlling apparatus; but the Otis Company presented wiring diagrams, showing the arrangements made for operating the motive-power with

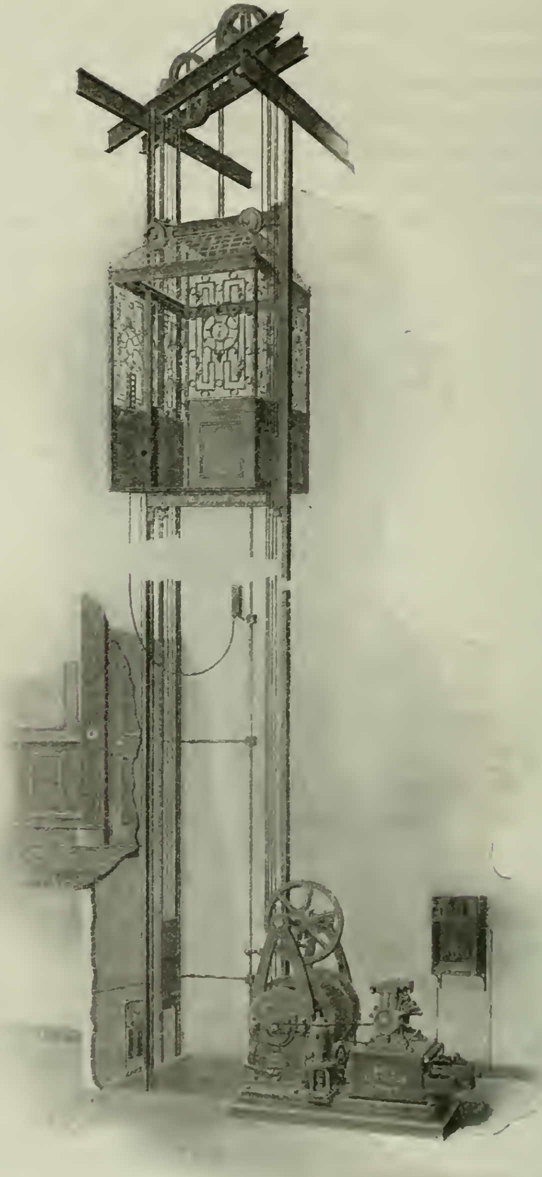
500 volts direct current, using a primary-battery circuit for operating the controlling mechanism, and diagrams for operating the motor-power with alternating current of high or low tension, but using primary-battery circuits or derived circuits for operating the controlling mechanism, the general principle being the same in all.

The operation of the particular apparatus examined was as follows:

The elevator hatchway is provided with a door on each floor and the elevator car itself is also provided with a door. On each floor is a single push-button on the landing, and in the car is a row of push-buttons, one for each floor and one additional stop or safety-button. The normal condition of the apparatus is with the motor stopped, the car at some floor-landing and all doors of the hatchway and the door of the car closed. Suppose the car to be at the second floor and a person standing on the fifth floor wishes to descend to the first floor. If every door is not shut and locked the car cannot be started nor can any of the landing-doors be opened except when the car is opposite that floor. A single push upon the button on the fifth-floor landing first throws the main regulating switch to the "up" position and starts the motor in the proper direction to bring the car up from the second floor. When it arrives at the fifth floor it automatically stops and releases the lock upon the fifth-landing door, permitting this to be opened. The passenger opens this door, and in so doing cuts the controlling circuit, leaving the elevator so that it cannot be moved by any one pressing buttons on any other floor. He enters the car, closing the landing-door behind him, but still cannot move the car as the door of the car is open. When this is closed, and only then, can he operate the car. On pushing the button for the first floor the main switch is immediately thrown to the "down" position and the car starts downwards. While the car is in motion the pressing of a button on any of the other floors or any other floor button in the car has no effect until the car has arrived at the floor for which it has been started. On arriving at the first floor the car stops automatically, and the passenger would first open the door of the car and by so doing cut out the main controlling circuit so that no one can start the car until he has opened the landing door, passed out of the car and closed both the car door and the landing door.

Should the passenger while in the car, with the car in motion, open the car door, the car would immediately stop wherever it might be, and could not be again started until the door was again closed.

It is evident that if at the moment of the car arriving at its destined floor, and before the car door had been opened,



some one should press a landing-button to call to some other floor, it would immediately start for that floor. It is to provide against this contingency that the safety or stop button is provided in the car. Pressing this button stops the car at once, wherever it may be, and places the control of the car again in the hands of the passenger. Another function of this stop-button is as follows:

Should the passenger, starting downwards (say from the fifth floor to the first), and after passing the third floor, change his mind and wish to return to the fourth floor, it will be seen from what has been said already, that pushing the fourth-floor button will have no effect. Pushing the stop button, however, stops the car and sets the various devices in such position that pressing the fourth-floor button will now send the car back to that floor without waiting for the car to descend to the first floor and make a fresh start from there.

A number of additional variations to meet special requirements were also shown, such as a provision that required the button in the car to be kept pressed down in order to keep the car moving. In such case, if the button is released, the car immediately stops. A signal bell is also provided to give an alarm, if from any reason the car should stop while a passenger is in it, and between floors.

The apparatus, as examined by the committee, seemed to be of the most thorough and substantial kind, with a notable absence of the delicate or flimsy construction so often associated with electrical devices. The contacts especially seemed ample and strong and fully able to stand the wear and tear of everyday unskilled operation.

For the ingenuity displayed in meeting the various combinations of an exacting service, and for the thorough and mechanical manner in which this apparatus has been developed so as to place it in the hands of the public upon a commercial basis, the Franklin Institute recommends the award of the John Scott Legacy Medal and Premium to the inventors.

Adopted Wednesday, October 1, 1902, and certified to be a correct copy from the committee's records.

WM. H. WAHL, *Secretary.*

CHEMICAL ANALYSIS OF IGNEOUS ROCKS.

The Geological Survey is about to publish a work of exceptional importance to students of igneous rocks and to geologists who have an interest in these objects. It is entitled "Chemical Analysis of Igneous Rocks Published from 1884 to 1900, with a Critical Discussion of the Character and Use of Analyses," by Henry Stephens Washington, and it will appear as No. 14 of the series of Professional Papers.

As its title indicates, it is a collection of all chemical analyses of igneous rocks published within a period of sixteen years, going back to the time of the last compilation of the kind by Justus Roth, a German geologist. All igneous rocks are products of the consolidation of liquid or molten magma. They are sometimes glassy, sometimes partly crystalline, and sometimes entirely so. It is evident from observation that any particular magma which has been erupted from the depths of the earth, through fissures, to the surface, where it issued in lava streams, has consolidated in different places with many different textures; and it is also known of many magmas that the resulting rocks may have different mineral composition, when fully crystalline, according to the influence of environment upon the cooling masses. The chemical composition is, therefore, the most fundamental or constant character of all these products from the eruption of any magma.

The tables of Dr. Washington give nearly 3,000 analyses of rocks from all countries in the world. It is interesting to note that by far the largest number, and also the best ones, are from the United States. The author lays so much weight on the character of the analyses that he separates the good from the bad on certain principles, and publishes them in two parts. The good analyses, some 1,600 in number, are arranged by kinds of rock, classed according to the recently published quantitative classification of igneous rocks by Cross, Iddings, Pirsson and Washington. The reason for using this new system is that the old rock names mean so little in regard to this fundamental feature of chemical composition that the analyses cannot be grouped in the most useful manner under those heads. The new classification, being based on chemical composition very largely, is suited to bringing analyses of similar rocks together. Certainly, the examination of the tables of good analyses shows that rocks which have practically the same chemical composition have been called by a great many different names under the old style of classification; and, of course, the converse is true, that the analyses of any rock family under the old classification are distributed among a good many divisions of the system adopted. The analyses which are too poor to enable anyone to classify the rocks according to the new system are grouped in the second part, under the old names. By means of double and complete indexes, however, the author facilitates reference to all analyses of any of the older systematic rock groups, such as granite or syenite. The geographic index refers to all rocks of certain regions.

An interesting discussion of the value of accurate analyses of rocks to the science of petrography precedes the tables, and reviews the means of judging as to the quality of an analysis. The author enters an effective plea for careful investigation in this direction.

The Acker Process for Alkali and Bleaching Powder by the Electrolysis of Fused Common Salt.

[*Being the Report of the Committee on Science and the Arts. Sub-Committee: C. J. Reed, Chairman; H. F. Keller, Samuel P. Sadtler, Carl Hering, Joseph W. Richards.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2242.] PHILADELPHIA, May 1, 1903.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the Apparatus and Process of Charles E. Acker, for Manufacturing Caustic Alkali and Bleaching Powder by the Electrolysis of Fused Common Salt, reports as follows:

The process and apparatus are the subject of United States Patents 649,565, 674,691 and 687,709, of May 15, 1900, and May 21 and December 3, 1901, respectively.

The early experiments with the process, as well as the description of its present installation, are set forth very fully by Mr. Acker himself in an illustrated article in the *Transactions of the American Electrochemical Society*, Volume I, 1902; further details may also be found in an article written by the chairman of this committee in the journal *Electrochemical Industry*, October, 1902, p. 54. In addition to this, Mr. Acker has written letters containing further details for the information of this committee, has given copies of works—analyses of his raw materials and products, and has sent large samples of the same to three members of the committee. Most of the members of the committee have conversed with Mr. Acker, and three members have thoroughly inspected his plant in operation at Niagara Falls.

It is unnecessary in this report to rehearse the already published details of the process and its operation. From actual inspection of the plant the committee is satisfied that the published information referred to is substantially correct. The actual operation of the plant is on such a scale as to leave no doubt as to its commercial practicability. From the facts submitted to the committee, it appears that the business can be operated profitably at present market values of the products and at the cost of power at Niagara Falls.

The various parts of the plant are well systematized and arranged. The mechanical appliances around the furnace and for handling and storing the various products are well worked out, and reflect credit on the company's engineers.

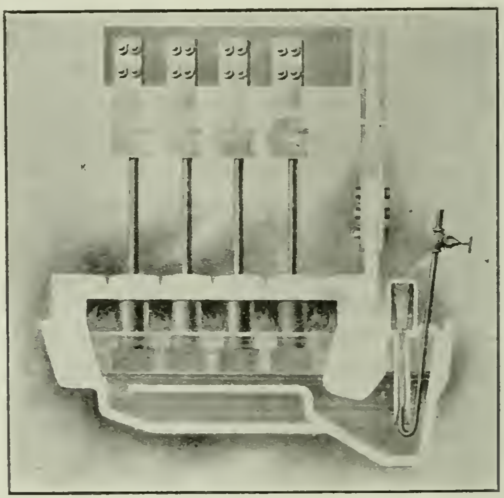


FIG. 1.

The electrolytic part of the plant is installed in a creditable manner, the avoidance of chlorine gas in the pot-room, by the use of powerful suction, being complete. The process itself attracts attention by its directness, the salt being decomposed in one room, the caustic produced passed through a window into the next, and there the settled caustic ladled into drums and sealed ready for shipment, all within a distance of perhaps thirty feet, and in two operations.

As compared with the wet electrolytic processes, the advantages of this system of working are: (1) its directness; (2) the very heavy current sent through each pot (as much through one Acker pot as through fifteen Castner cells); (3) the absence of the evaporation of caustic and boiling down to dryness; (4) the absence of water solutions, requiring special pumps and a complicated circulating system; (5) the absence of the use of mercury. The disadvantages of this system are: (1) a larger power requirement—6·75 volts in place of 4·5, or some 50 per cent. more; (2) the rapid destruction of the apparatus; (3) the rapid destruction of the anodes; (4) the more arduous work of the pot-men.

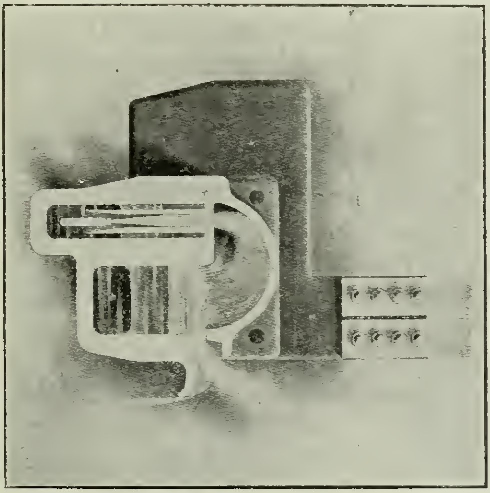


FIG. 2.

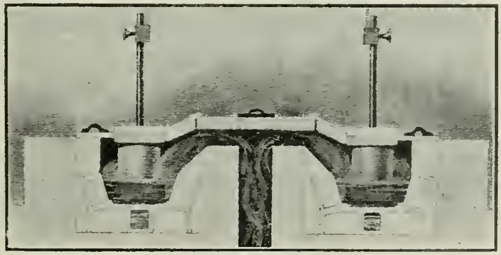


FIG. 3.

The committee wishes to commend the perseverance with which the Messrs. Acker have worked at their experiments and finally brought them, as it were by main force of pluck and determination, to a commercial standing. There are still improvements possible in the working of the plant, particularly regarding the durability of the pots and the simplification and better preservation of the anodes; but these are points for future advance, and their presence and evident capability of improvement give hopes for a still better working of the process.

Some calculations made by the committee may be of scientific and practical interest: Of the total energy of the current used, 54 per cent. is usefully applied to the chemical separation of sodium from chlorine, 9 per cent. is utilized in melting the salt used, and 37 per cent. is radiated from the apparatus.

As regards the quality of the products, two chemical members examined them and report that they found the bleaching powder to be substantially as given by Mr. Acker's analysis, but that the caustic soda, while of good commercial quality, contains more sodium chloride and carbonate and less caustic soda than Mr. Acker's analysis shows. In view of this, the recommendation is made to Mr. Acker that more care should be exercised to prevent the carbonation, and particularly the entrance of sodium chloride accidentally into the fused caustic, during its collection in the pot-room.

In view of the above recited facts and observations, the Franklin Institute of the State of Pennsylvania awards the Elliott Cresson Medal to Mr. Charles E. Acker, for his apparatus for and process of producing caustic soda and chlorine by the electrolysis of fused common salt.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, December 3, 1902, and certified to be a correct copy from the committee's records.

WM. H. WAHL, *Secretary.*

The Goldschmidt Theory of Harmony.

[*Being the Report of the Committee on Science and the Arts, with Appendix. Sub Committee: Jos. W. Richards, G. A. Hoadley, A. S. Mackenzie, E. Goldsmith, C. C. Heyl, J. F. Walls.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2222.] PHILADELPHIA, November 1, 1902.

Dr. Victor Goldschmidt's "Harmonie und Complication" sets forth a new view of musical harmony which your committee has been asked to pass upon. In reality, the treatise referred to is the announcement of a new law governing the development of our perception of harmonies in colors, proportions and taste, as well as the harmonies of sound.

The author takes up the subject as a crystallographer. He has made a particular study of the relations to each other of the planes upon the surfaces of crystals, particularly of those series of planes which lie extended or developed in zones between two primary or reference planes. By the method of gnomonic projection, the reference planes and the planes between them are represented by points on a straight line. The author's theory that the crystallizing forces building the primary planes unite in simple multiples to produce resultant forces which build the intermediate planes, is so well proven and so clearly explains the facts that it has been generally accepted as the correct explanation of the genesis of crystal forms, and the modern nomenclature of crystal form (Miller's) is being interpreted and taught in the light of this theory. The author's contributions to practical and theoretical crystallography have been of the highest value in the modern development of that branch of science, and have placed his name in the front rank of modern crystallographers.

The "law of complication," as applied to crystal faces, is simply a statement of the fact that if the forces which build the primary pinacoids or primary planes of a zone are taken as the original crystallizing forces, their combination in simple numerical proportions (as would be, in fact, indicated by Miller's indices), produce resultant forces, which are respectively the builders of the other planes in the zone. The truth of the theory is seen in the striking manner in which all the important laws of crystallography may be derived from it as corollaries. Its truth implies as one corollary that Miller's indices for crystal planes will all be simple whole numbers, since they really represent the proportions in which the primary crystallizing forces unite to produce any plane. This change in the point of view of regarding or interpreting Miller's symbols is a magnificent advance in practical crystallography, and has facilitated very greatly the obtaining of correct fundamental ideas on crystal genesis, particularly on the part of students. Another corollary is the law of the simple mathematic ratio, which postulates the simple numerical relations existing between the relative distances cut off on the axes of reference by different planes, or their simple numerical relation to the arbitrarily chosen fundamental intercepts of the fundamental pyramidal plane. Still another corollary is the zone equation, or the equation of condition governing the relation to each other of the intercepts of planes which lie in one zone. Another deduction is the harmonic ratios existing between the intercepts, on the same axis, of all planes lying in a zone. In short, all of the important laws and generalizations which have been so far made in crystallography are found to be necessary deductions from the theory of the genesis of planes according to the "law of complication" as put forward by Dr. Goldschmidt.

The fact of the "harmonic ratio" existing between the intercepts of planes on one axis led Goldschmidt to the query as to whether the distribution of the notes in our harmonic scale might not be governed by the same kind of a law of complication which appears to govern the distribution of the planes in the zone. To test this question, Goldschmidt applied his crystallographic nomenclature to the notes of the ordinary octave. He said, let *c*, whose relative number of vibrations we take as 1, represent one of our primary crystal planes, with a symbol of *o*; let upper $\bar{c}$, with vibrations equal to 2, represent the other primary plane, with the symbol ∞ (infinity); then let us give the appropriate and necessary symbols to the intermediate notes, which is easily done by taking for each its relative number of vibrations and dividing its distance from 1 by its distance from 2. The octave being thus transformed into a zone, stretching between c equals o and $\bar{c}$ equals ∞, the intermediate notes, with the exception of d and b, are found to correspond with the ordinary development of a zone in a crystal. If a similar zone is stretched from g (3/2) to upper $\bar{g}$ (6/2), a similar zonal development is observable, with d and b important members of this series. The conclusion is then deducible that our octave consists of two real harmonic series superposed on each other, one between c and $\bar{c}$, the other between g and $\bar{g}$.

The next deduction from this observation is, that only those notes can form an agreeable chord which belong to one series, and that, therefore, musical chords can be likened to crystal zones, in which the possible occurrence of all harmonious parts is governed in both cases by the law of complication.

Our author elaborates this thesis at length, and whether his method of regarding the genesis of a chord is in reality correct or not, there is no denying the fact that his conception does apply to the understanding or explanation of musical chords as we know them.

Regarding the succession of chords in a sequence, the ground tones on which the successive chords are built are to be considered. The ground tone is that note in any chord which must be regarded as o in the crystallographic nomenclature, and between which and its octave, ∞, the zone or harmonic series is developed according to the law of complication. If the ground tones of successive chords are thus regarded, it is found that there is no arbitrary or accidental succession of ground tones, but that they all belong, in one line or musical unit, to one succession or zone of notes, which are related among themselves by the same law of development or complication. This gives a running chord as the law of sequence for the ground tones, and no ground tone may be introduced foreign to that zone or set of related notes. Thus we obtain a chord of succession for the ground tones, which itself has a ground tone. Other parts of a composition may have other ground tones for the chords which govern the succession of its minor ground tones; but all these ground tones of the third order, if we may so call them, are again related to each other by the law of complication, and thus furnish a ground tone for the whole composition.

To thoroughly understand the reasoning of Dr. Goldschmidt is not easy. Your sub-committee have met several times and discussed the subject at length among themselves, and have persevered in the endeavor to follow and understand the author's thought and method. It is quite clear, for instance, to all the committee that the application of Goldschmidt's method to simple melodies, such as "Gaudeamus Igitur," explains most clearly and undeniably the musical structure and composition of the piece. The proof here is convincing that the method of interpretation is sound and of utility in helping to grasp the nature of the composition, and see into its musical structure. Further on, the author analyzes one of the most difficult of compositions, Palestrina's "Stabat Mater Dolorosa," a composition which the great Helmholtz designated in his "Lehrbuch der Tonempfindungen," as "a mass of notes thrown together in the most promiscuous manner, violating every modern rule of harmony, and yet a composition of undeniable musical power," and further remarked that "the master key which would enable us to unlock the tangled threads and understand the musical structure of the piece has yet to be found." Analyzing this *crux experimentis* by the same rules of the law of complication, Goldschmidt arrives at a graphic and striking exposition of harmonious structure and development in this composition, which is quite as plain as his analysis of the "Gaudeamus Igitur." The proof is convincing that the key to the harmonies of this masterpiece has been found; the master key, whose absence Helmholtz regretted, has unlocked the secrets of its musical structure.

Just at this point, however, your committee are not unanimous. We all admit that Goldschmidt has discovered *a key*, but the member most competent to speak as a musician cannot admit the necessary conclusion from Goldschmidt's analysis, that the piece is based on the ground tone *A* flat. His modern musical training prevents him from seeing the possibility of that conclusion being correct, yet he admits that if he studied out more at length the different modes prevalent in Palestrina's time, the conclusion may not be impossible; yet it is unexplainable in our modern way of interpreting keys.

The majority of your committee feel, however, that the proof that Goldschmidt's method of analysis and explanation is correct is so abundantly shown by his analysis and demonstration of musical symmetry and harmonious structure in that hitherto unexplained masterpiece—the "Stabat Mater" of Palestrina—that they cannot but regard the divergence of Goldschmidt's conclusion, as to the fundamental ground tone of the piece, from that which modern musical theory ascribes to it, as being due to the discrepancies of the latter; for a theory which was admittedly unable to explain the structure of the composition has no grounds for refuting the necessary conclusions of a theory which does explain, in a most striking manner, all the intricacies of the composition.

The verdict of your sub-committee is that so purely original and scientifically important a work deserves the highest recognition which is in the power of the Institute, and therefore recommend that "The Elliott Cresson Gold Medal" be awarded to Dr. Victor Goldschmidt, of Heidelberg, for his contributions to the science of music, as embodied in his work, "Ueber Harmonie und Complication."

As an appendix to this report, we present a simplified presentation of the theory elaborated by Dr. Goldschmidt, written by the chairman of your sub-committee, which will explain to the general scientific public the ideas and conclusions of the work examined.

Certified as a correct copy from the committee's report.

WILLIAM H. WAHL, *Secretary.*

APPENDIX.

The Goldschmidt Theory of Harmony.

BY JOSEPH W. RICHARDS, PH.D.

(*Read at the meeting of the Physical Section of the Institute, January 22, 1902.*)

Dr. Victor Goldschmidt is professor at the University of Heidelberg, and one of the best-known crystallographers in Europe. His "Index of Crystal Forms" and his "Angle Tables" are monuments of industry and research; he is a frequent contributor to Groth's *Zeitschrift für Krystallographie und Mineralogie.* His development of the methods of gnomonic projection, and of the application of the "two-circle" or "theodolite" goniometer to crystal measurements, has made his unpretentious laboratory, of but three small rooms, the Mecca of numerous American students of crystallography.

Less than a year ago, the genial professor surprised his friends no less than the scientific public by publishing an octavo book of 136 pages* on the subject of musical harmony, and the application to it of the law of inter-relation which governs the distribution of planes in zones on the surfaces of crystals. This law was discovered by Goldschmidt in his crystallographic studies, and is called by him "Das Gesetz der Complication," which we may translate rather freely as "The Law of Inter-relation." This law is the most general law of crystallography; it explains the distribution of all possible planes between two primary planes. It is so fundamental that it includes as corollaries the formerly recognized fundamental laws of crystallography, viz., the law of the rationality of the indices, the law of zones, and the law of constancy of the angles. But not only is this law the primary law of crystallography: Goldschmidt believes he has proved that the same fundamental law governs, in musical harmony, the harmony of notes in a chord, the sequence of related notes, and the rela tions between a sequence of chords. In fact, "Das Gesetz der Complication" is also the fundamental law of musical harmony.

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* "Ueber Harmonie und Complication." Springer, Berlin, 1901.

Further than this, although foreign to our present subject, an application can be made of the same law in discussing the harmonies of colors, the historical development or evolution of the color sense, and also to the æsthetic sense of proportions. Goldschmidt makes some very suggestive inquiries in these directions, which will be of particular interest to the psychologist. If these generalizations are true, if it can be proved even in the one case alone, of musical harmonies, that what sounds well to the ear, and therefore commends itself to the mind as agreeable, is that which corresponds to harmonious development in the objective realities of crystal forms, then we have a purely objective explanation of our subjective discriminations. What sounds agreeable to our minds is that which has its real harmonious counterpart in objective nature, and thus the final source of mental satisfaction is that one finds his mental processes in accord with the great harmonies of Nature.

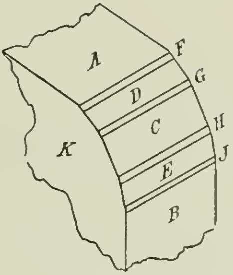

Fig. 1.

THE LAW OF INTER-RELATION IN CRYSTALLOGRAPHY.

Among the planes occurring on one crystal, and which may be great in number, certain planes are particularly important because of frequency of occurrence and size, others occur seldom, while others are quite rare. The rarer the plane, in general, the smaller it is, and the less certain is its identification. The feebler planes are arranged in series between the principal or primary planes, in zones, with parallel intersections.

Let *A* and *B* (*Fig. 1*) be two primary faces (*K* may be a third). Then, by differentiation there is first formed between them the plane *C*, truncating with parallel edges the edge between *A* and *B*. If the differentiation proceeds further, we may have *D* and *E* truncating the edges between *A C* and *C B* respectively. The planes *D* and *E* are subordinate to *C*. By still further differentiation there are formed the still feebler truncating planes *F*, *G*, *H*, *I*. We thus have, so far, three stages of differentiation or development in the history of this zone.

$N_0 = A$								*B*
$N_1 = A$				*C*				*B*
$N_2 = A$		*D*		*C*		*E*		*B*
$N_3 = A$	*F*	*D*	*G*	*C*	*H*	*E*	*I*	*B*

Usually the development stops at N_1, often it goes to N_2, seldom to N_3, and very rarely to N_4 or over. The first derived plane, *C*, the most important next to the primary planes, is called the "dominant."

A similar development can take place on the edge between *A* and *K* or *B* and *K*. We would call these the "primary zones" *A B*, *A K*, *B K*, between the primary planes or nodes *A*, *B*, *K*. Further differentiation between one of the primary planes, as *K*, and the "dominant" of the other two, as *C* between *A* and *B*, gives us "secondary zones," such as *C K*, each with a "secondary dominant." Differentiation between two "prime dominants" would give tertiary zones, with "tertiary dominants;" while differentiation between a prime dominant and a secondary dominant would yield "quaternary zones" with "quaternary dominants." Zones, therefore, have their orders, though very seldom is the order above secondary. This scheme of development gives a rich mass of zones, especially if the primary faces are well developed and the differentiation between them goes up to N_2 or N_3.

In every zone, on every crystal, the arrangement of the planes relative to each other and to the primary planes of that zone follows a determined law of numbers. If, by a simple geometrical device, the primary planes be represented in position by 0 and ∞ respectively, the dominant will be represented by 1, and the subordinate planes by $\frac{1}{2}$ and 2, $\frac{1}{3}$ and 3, $\frac{2}{3}$ and $\frac{3}{2}$, etc., forming as a whole a harmonic progression such as $0\ \frac{1}{3}\ \frac{1}{2}\ \frac{2}{3}\ 1\ \frac{3}{2}\ 2\ 3\ \infty$. These we may call harmonic numbers or the harmonic series. We will proceed to show how it applies to crystal planes in a zone.

Assuming that the physical particles which build up the crystal have primary forces of determined direction and intensity, and that these are the constructive forces which attract other particles and build up the crystal planes, we may further assume that the plane-building forces are perpendicular to the faces formed. The primary crystal-building forces are therefore perpendicular to the primary crystal planes, and the secondary or derived forces are perpendicular to the secondary or derived planes. Considering, therefore, each plane of a crystal to be built by a force at right-angles to that plane, we may replace all the planes by their normals, and discuss these normals as representing the plane-building forces.

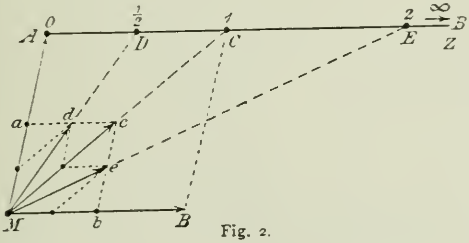

Fig. 2.

Taking the planes already illustrated in *Fig. 1*, we may, from any point inside the crystal, drop perpendiculars to the respective faces. Let *M* (*Fig. 2*) be the point chosen; then the primary planes *A* and *B* of *Fig. 1* are here replaced or represented by their normals *A* and *B*, the intermediate plane *C* by its normal *c*, *D* and *E* by their normals *d* and *e*, etc. The replacing of planes by their normals is a common device in mathematical crystallography. The primary forces *A* and *B* have therefore a determinate direction, the angle between them being the same as the angle between the planes themselves, and the relative intensities of these forces are as the reciprocals of the axial ratios in the respective directions. Given, then, these primary forces of given direction and intensity, the "law of inter-relation" considers the differentiation or development of subordinate planes to have proceeded in the following manner:

The forces A and B split into two halves; one of each of these halves, a and b, unite to form the resultant c. The plane C results normal to c. The process repeating itself, $\frac{1}{2}\, a$ unites with $\frac{1}{2}\, c$ to a resultant d, and likewise $\frac{1}{2}\, b$ and $\frac{1}{2}\, c$ to e. By further repetitions of the same process still further, feebler resultants form between $a\ d$, $d\ c$, $e\ b$, etc. So we find the directions of the derived forces, and thence the position and order of rank of the derived planes. The planes stand normal to the forces, the order of rank corresponds to their relative importance in the order of development.

By drawing through A a parallel to B, and lengthening the forces $M\ a$, $M\ d$, $M\ c$, etc., until they intersect $A\ Z$, the directions of the forces are characterized by the points of intersection A, D, C, E, B. B lies at infinity. Calling $A = 0$, the starting point of measurement on $A\ Z$, and $A\ C = 1$, because it represents equal components of a and b; then will $A\ D = \frac{1}{2}$, $A\ C = 1$, $A\ E = 2$ and $A\ B = \infty$. The intersections on $A\ Z$ may be called the projection points of the different planes in the zone $A\ B$; the projection points characterize the position of the planes; their place is designated by the distances from A, by the numbers $0, \frac{1}{2}, 1, 2, \infty$. These numbers are the harmonic numbers, their series the harmonic series, and, if complete, the normal series. The law of development is expressed in the normal series and the harmonic numbers as follows:

Primary planes:	A				B
$N_0 =$ Normal series $0 =$	0				∞
1. Complication:	A		C		B
$N_1 =$ Normal series $1 =$	0		1		∞
2. Complication:	A	D	C	E	B
$N_2 =$ Normal series $2 =$	0	$\frac{1}{2}$	1	2	∞

3. Complication:	A	F	D	G	C	H	E	I	B
$N_3 =$ Normal series $3 =$	0	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{2}{3}$	1	$\frac{3}{2}$	2	3	∞

It is clear how the higher series would look, but nature very seldom develops planes above the series N_3.

To investigate any series of numbers, so as to test them as to harmonic relations, it is necessary to make a transformation, to substitute for the end members 0 and ∞, and for the intermediate members their corresponding values. These intermediate values are easily found by dividing the distance of the number from one end by its distance from the other. Thus, given the series of members,

$$1 \quad \frac{4}{3} \quad \frac{3}{2} \quad \frac{5}{3} \quad 2$$

if we call the extremes 1 and 2, 0 and ∞ respectively, the intermediate members become—

$$\frac{4}{3} = \frac{\frac{4}{3} - 1}{2 - \frac{4}{3}} = \frac{1}{2}$$

$$\frac{3}{2} = \frac{\frac{3}{2} - 1}{2 - \frac{3}{2}} = 1$$

$$\frac{5}{3} = \frac{\frac{5}{3} - 1}{2 - \frac{5}{3}} = 2$$

and the series becomes in harmonic numbers—

$$0 \quad \frac{1}{2} \quad 1 \quad 2 \quad \infty = N_2$$

Or, in general, calling Z and Z_2 the two extremes of any series of numbers, Z any intermediate number, and p the corresponding harmonic number of a harmonic series, then—

$$p = \frac{Z - Z_1}{Z_2 - Z} \text{ for } Z_1 = 0 \text{ and } Z_2 = \infty$$

The study of crystal forms, particularly by the method of gnomonic projection, in which all zones are projected in straight lines, and the position of planes in series can be directly measured or calculated, has substantiated the "law of inter-relation" as being the law governing the distribution of planes in zones. We will now study the diatonic scale in the light of the same law, transforming its members into harmonic series, and therein making clear the fundamental relations of the various notes to each other.

[*To be concluded.*]

Notes and Comments.

TESTS OF NERNST LAMPS FOR PUBLIC LIGHTING.

At a recent meeting of the British Institution of Electrical Engineers in London the results of the experiments with the Nernst electric light for public lighting purposes were given. A mile of a street in Hackney, one of the London suburbs, has been lighted by means of these lamps to obtain conclusive data regarding their durability, efficiency and suitability for such work. The main difficulty experienced was in connection with the starting of the light. This, however, was overcome by means of the automatic heater, which is put out of action directly the lamp lights up. But the result of this attachment was not attended with absolute success, since considerable uncertainty exists in connection with the durability of the glower. Some glowers lasted only 15 hours, while others remained efficient for 1,070 hours, but the average life was 305 hours. This lack of uniformity constitutes one of the greatest objections to the wider utilization of the Nernst lamp for public lighting, despite its superiority in many important features, and will necessitate considerable improvement before it is extensively adopted for illumining the streets, with that economy which is essential for such purposes.

STRANGE FACTS ABOUT THE EUCALYPTUS.

Mr. D. E. Hutchins, of Cape Colony, who in 1882, in conjunction with Sir A. Brandis, discovered the remarkable sun-power storage capacity of the eucalyptus, has again been drawing attention in *Nature* to this extraoadinary feature of the tree. According to Mr. Hutchins, a eucalypt plantation in tropical mountains, such as in South Africa, under favorable circumstances, stores up about one per cent. of the solar energy received on the unit of area and it is considered much cheaper in some parts of Cape Colony to plow up the land and plant a forest of quick-growing trees than to import coal.

In 1882 Mr. Hutchins and Sir A. Brandis, as the result of their experiments, discovered that eucalypts planted on tropical mountains produce fuel at the rate of 20 tons—dry weight at 60 pounds per cubic foot—per acre per year in perpetuity. The eucalypt plantation reproduces itself when cut without further expense, and its dry timber, heavier than coal, has an equal or a higher thermal power, bulk for bulk, than coal. This result was obtained as a measurement of the maximum yield of *Eucalyptus globulus* on the Nilgiris, Southern India. If a chance tree on a chance mountain in a chance soil can produce the equivalent of 20 tons of coal per acre per year, it seems not unreasonable to suppose, Mr. Hutchins suggests, that by selection double this, or 40 tons, can be produced. A powerful sun, a heavy rainfall, and a very rapid forced growth are the essentials of such a production of wood fuel. A glance over the rainfall map of the world shows these conditions are fulfilled over about 8,000,000,000 acres of its surface, which is between one-fourth and one-fifth of the total land surface of 35,200,000,000 acres. One-half of this area under forest might thus yield the equivalent of 160,000,000,000 tons of coal yearly, which is more than 288 times the world's present consumption of coal, assuming that coal and eucalypt timber are of approximately equal heating power. On the basis of the actual forest yield of the present day, we have half of this, or the equivalent of 80,500,000,000 tons. In Germany, one fourth of the total area is under forest, and taking the German standard of one-fourth forest, on the basis of the present maximum yield we should obtain 40,250,000,000 tons; while if the maximum forest yield be converted to an average forest yield there would still remain a yearly product of 20,175,000,000 tons, which is rather more than thirty times the world's present consumption of coal. Thus it is seen that the yield of firewood from the world's tropical and extra-tropical forests, wherever they are fully stocked and scientifically worked, will yield the equivalent of from 30 to 122 times the present consumption of coal, or even up to 243 times the present consumption, if by cultivation the present timber yield be doubled, as it might be without difficulty.

THE ANCIENT RUINS OF RHODESIA.

The remarkable ruins in South Africa, which by many are boldly declared to be the remains of King Solomon's mines, are fully described and illustrated in a recent work by R. N. Hall and W. G. Neal. No theories are offered for the presence of the ruins in savage lands. The authors, however, seem to incline to the opinion of Prof. Keane, which is, in brief, that "the 'gold of Ophir' came from Havilah (Rhodesia), and was worked and brought thence first by the Himyarites (Sabæans and Minæans), later by the Phœnicians. . . . The numerous objects of Semitic worship and the fragments of Himyaritic script found at Zimbaye and elsewhere south of the Zambesi leave no reasonable doubt that the old gold-workings and associated monuments of this region are to be ascribed to the ancient Sabæans of South Arabia and their Phœnician successors."—*Scientific American Supplement.*

THE USE OF PHOSPHORUS MATCHES PROHIBITED IN GERMANY.

The Reichstag has passed a bill forbidding the use of white or yellow phosphorus in match-making after January 1, 1903. The Secretary of the Interior, speaking in favor of the bill, said that phosphorus not only caused necrosis three or four years after a workman had left a match factory, but that the disease thus contracted was hereditary, so that whole families were affected. So subtle were the effects that the bones were fractured without the person at first being even aware of the fracture. The Government has reported favorably upon a match-manufacturing process said to be safe and harmless.—*Scientific American.*

ALCOHOL AS FUEL FOR INTERNAL COMBUSTION ENGINES.

Tests made by C. W. Weiss, at the Mietz & Weiss Engine Works, New York City, with Cuban and Brazilian cheap alcohol as fuel in their standard kerosene engine, have been reported as entirely satisfactory. The object was to substitute alcohol for kerosene, the former being considerably cheaper and more readily obtainable in Cuba and South America, where many of these engines are shipped. It was found that a mixture of 4 pints alcohol and 2 pints water developed 4 horse-power for one hour. The mixture of alcohol varies, however, with the quality of the former being limited by the practical degree of compression prior to combustion. The specific gravity of the mixture is 0·9 ; that of the pure alcohol was 0·794. The development of the alcohol engine is of the greatest importance to the power question of Cuba, Brazil and the Philippine Islands.

A NEW POWER PLANT AT NIAGARA FALLS.

It is stated on good authority that the Lackawanna Steel Company will use power from Niagara Falls to operate the immense amount of machinery at their new plant at Stony Point, Buffalo. Arrangements have not been entirely completed, but the directors have contemplated this step for some time, and plans have been drawn for part of the work. It is the intention of the company to install their own generators at the Falls by special arrangement with one of the existing power companies or by the purchase outright of one of the smaller power companies, and to connect same with their steel plant by their own special line of wires.

INGENIOUS DANGER SIGNALS.

Some of the devices invented for use upon railways are exceedingly practicable as danger signals, but why they are not generally adopted is one of the things that are not easily understood. One of them is a torch which is attached to a pointed rod easily driven into a tie to keep it upright. By unscrewing a friction cap on the torch itself a bright red light, which neither rain nor wind can extinguish, burns for fifteen minutes, and is visible for one mile, making it unnecessary to send a brakeman back with a red flag.—*Iron Age.*

PRODUCTION OF MAGNESITE IN 1902.

The report on the production of magnesite in 1902, by Dr. Joseph Struthers, will soon be issued by the United States Geological Survey.

The production for 1902 was 3,466 short tons, valued at $21,362, as compared with 13,172 short tons, valued at $43,057, in 1901. The imports of crude and calcined magnesite during 1902—chiefly from Greece and Austria—amounted to 49,786 short tons ($373,928), as compared with 33,461 short tons in 1901.

In the crude state magnesite is used in the manufacture of carbon-dioxide gas, by treatment with sulphuric acid or by the application of heat alone. In the former case magnesium sulphate is obtained as a by-product, which yields Epsom salts, the production in 1902 being estimated at about 50 000 barrels. The chief use of the carbon-dioxide gas derived from magnesite is to charge or carbonate mineral waters. In its calcined state the consumption of magnesite has increased very largely since 1899, owing to its use as a refractory lining for furnaces and kilns. As a commercial product the mining of magnesite is practically confined to California, and principally to Tulare County.

Book Notices.

Annuaire pour l'an 1903, publié par le Bureau des Longitudes: avec des notices scientifiques. In—16 de près de 850 pages avec figures. Paris: Gauthier-Villars (1 fr. 50; franco, 1 fr. 85).

The house of Gauthier-Villars issues as usual the *Annuaire des Bureau des Longitudes* for the year 1903.

This compact little volume contains the customary collection of astronomical and physical data which makes it so indispensable to the engineer and the man of science. Appended thereto are some interesting scientific notes, among which may be mentioned communications by M. R. Radase, on Shooting Stars and Comets; by M. J. Janssen, on Science and Poesy; and finally, the discourses pronounced at the obsequies of MM. Fayl and Cornu. W.

Analysis, Detection and Commercial Value of the Rare Metals. By J. Ohly, Ph.D. 8vo, pp. 216. Denver, Colo.: Industrial Printing and Publishing Company. 1903.

The recent advances in the field of illumination and the manufacture of special steels has brought the rarer metals, such as tungsten, vanadium, molybdenum, titanium, thorium, cerium and its allies, the rarer platinum metals and others, into prominence, and a handbook giving the most reliable analytical methods for their detection and estimation should prove very useful to chemists and others who are called upon to identify these substances. The author has endeavored to cover this ground. W.

The Bonus System for Engineering Works. The Cassier Magazine Company, 3 West Twenty-ninth Street, New York. (Price, 10 cents.)

The publishers of the *Cassier's Magazine* have just issued in pamphlet form the article on the Bonus System which appeared in their Machine Shop number, published a few weeks ago. Of the various methods of encouraging increased production among workmen, especially in engineering works, no system has ever produced such satisfactory results as some form of a bonus system, but a bonus system without some method of imparting the necessary information both to the employer and the employee is not likely to prove workable. This pamphlet deals not only with the system, but with the method of accomplishing what the system aims to accomplish—increased production and satisfied workmen.

Experiments with Vacuum Tubes. By Sir David L. Salomons, Bart., M.A. (With 54 illustrations.) 12mo, pp. vii + 79. London and New York: Whittaker & Co. (Price, 2 shillings.)

The author presents in this booklet some new methods which he has devised for the study of the phenomena caused by the electric discharge in so-called vacuum tubes. He has observed that many of those phenomena are obscured or confused, and their correct interpretation rendered difficult if not impossible by reason of the employment of currents of very high E.M.F. and large currents. He accordingly employed in his study of the phenomena very small E.M.F. and very small current. By this method, he claims, the difficulties which beset earlier investigators disappear and the phenomena are seen in their purity. Then on raising the E.M.F. successive superadded phenomena appear, which would have been extremely puzzling had the start not been made in this manner. Then follows a detailed account of numerous experiments under varying conditions with a great variety of tubes.

A second part of the book describes the author's observations on the effects produced upon electric discharges in rarefied gases when placed in the magnetic field. W.

Report of the Commissioner of Education for the year 1900–1901. Washington: Government Print, 1902.

This publication, comprising nearly 1,300 pages octavo, exhibits very creditably the thoroughness with which this Bureau conducts its business of inquiring into the questions bearing on education in the United States.

In all there are nineteen chapters treating respectively of the following themes: Co-education of the sexes in the United States; Education in the Philippine Islands; foreign universities, etc.; education in Alaska; domestication of the reindeer in Alaska; Consular reports, city school systems; universities, colleges and technical schools; professional and allied schools; agricultural and mechanical colleges; normal schools; secondary schools; manual and industrial training; commercial and business schools; education of the colored race; reform schools; schools for the defective classes; instruction in mining engineering; current topics; miscellaneous educational topics. W.

Report on the Engineering Trades of South Africa. By Ben. H. Morgan, Special Commissioner, etc. (With numerous tables, appendices and reproductions of special plans, drawings and photographs.) 8vo, pp. xii + 192. London: P. S. King & Son (for the National Industrial Association), 1902.

The author was named by the English "South African Trade Committee" as special commissioner to visit South Africa, and, after personal inspection and inquiry on the ground, to report upon the condition of the engineering trades of that country, in the general interest of British manufacturers and merchants.

The work contains the results of the author's mission. American manufacturers especially will be interested in consulting it. W.

Outlines of Electrochemistry. By Henry C. Jones, Associate Professor of Physical Chemistry in the Johns Hopkins University. 8vo, pp. vi + 106. New York: D. Van Nostrand Company. (Price, $1.50.)

This volume, in a concise and lucid manner, presents the most recent theories of chemical action which have caused so radical a change in the views of chemists. None is better qualified than the author to present this subject in the most intelligible and interesting manner. W.

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THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, June 17, 1903.

Controlling the Floods of the Mississippi River.

BY PROF. LEWIS M. HAUPT.

Mr. President, Ladies and Gentlemen:

The subject assigned by your committee for this evening is a large one, so that in the time at command it will only be possible to treat of a few generalities. Your attention will therefore be directed chiefly to the humane aspects of the problem, followed by some of the physical conditions which characterize the progress of the improvements, with their results and suggestions as to the remedies which may be applied to still further alleviate the disasters which are all too frequent. Already this season there have been two severe inundations which have risen higher than any previous records, causing great destruction of life and property; but such losses are not unprecedented, for in 1897 the *Public Ledger* said, editorially:

"One of the greatest problems that confronts the Government is the control of the lower Mississippi. Its present condition shows the problem in its fullest force. Levees are broken, towns are inundated, miles of country under water, hundreds of families homeless, many lives lost, and all destructible property over an area of hundreds of miles destroyed. This is a condition likely to occur any year, and it must keep a large section of the most productive land in the United States from being developed, so long as it remains unremedied. Few people will care to settle in a territory where they are liable to be drowned and certain to have their stock and dwellings washed away whenever there is an extraordinary rise in the river. It is a problem not easily solved, for even the expensive operation of building levees affords only temporary relief. This plan, pursued on the Yellow River of China, has had the effect of raising the level of the river above that of the surrounding country, so that when the levees break, as they do every once in a while, a vast tract is inundated and the destruction of life and property is enormous. Can American ingenuity find any better scheme for curbing the Mississippi?"

This prediction was verified a few years after, for, on October 15, 1901, it was officially reported that the floods of the Yangtse Valley had reached their highest stage in fifty years, wiping out villages, destroying crops and drowning thousands of people. Despatches just received from the Kwang-Si district state that 150,000 persons are in danger of starvation, and that women and children are being sold to procure food.

In our own country similar catastrophes have been recorded, beginning with the melting of the snows in the spring, causing the early floods in the Ohio, which have formed numerous crevasses in the levees and a higher stage in the Mississippi River than has ever before been recorded. The stories of suffering, devastation, heroic rescues and deaths have been so constantly presented as to appeal earnestly to the sympathies of the more fortunate sections of the country, and no sooner had the waters subsided than a similar disaster was inflicted upon Topeka, Kansas City, St. Louis and other points from the discharge of the western affluents of the basin. At the same time that these northern sections were suffering from an excess of water, the southern portion of Louisiana was praying for rain to save the rice, cotton and sugar crops from destruction by drought in consequence of the exclusion of the water from the land. What is needed, therefore, is a more equable distribution of water for fertilization and a more uniform stage in the river for navigation. The problem is as old as the world and has been successfully applied in the fertile river bottoms of Mesopotamia and Egypt, which for thousands of years were the principal sources of supply of food to mankind.

In this country, however, the present practice seems to be based not so much on experience in olden times as upon experimentation to meet existing conditions, and in commenting upon the results secured to date, the New York *American* says: "The country is stunned by the appalling horror of the calamity in North Topeka, where fire and flood have combined to slay hundreds. It seems incredible . . . and that such a disaster should have been possible is an arraignment of the engineering skill and foresight of our time.

"The world should by this time have reached a stage where the safety of cities from river floods should be a certainty. . . . Because we have not progressed to this attainable stage, Kansas, Nebraska, Missouri and Iowa are to-day mourning their dead."

In behalf of the engineering profession, it seems necessary to state that the responsibility for these disasters does not rest with it, since Congress has the sole jurisdiction and control of these questions, and its attention has frequently been called by engineers and river men to remedial measures which have not been adopted. The real causes may better be ascribed to politics and local interests, as may be illustrated by the following reported interview with one of the most sagacious railroad magnates of this country, now deceased, who, on being requested to lend his aid to the passage of an Act which would have provided earlier relief to the Mississippi Valley, is said to have replied:

"I have read all of the arguments before Congress. The outlet system is correct and the only way to deepen the Mississippi River. If that were done, what would become of not only my own, but all other railroads coming to New York? They would be ruined, and for that reason he would favor the levee system, for so long as that be kept up, there need be no fears of the Mississippi as a competitor."

A Chicago editor added, whether pertinently or impertinently: "The New Yorkers do not intend to let anything be done that does not pay tribute to New York."

Alas for the rarity of human charity.

It is an unfortunate fact that sectionalism permeates so many of the measures presented to Congress and militates against the general development of the entire country. In this particular instance, however, there is a natural belief that the best means of protecting property from inundation, is to surround it by an earthen dam or dike, so that the earlier settlers in selecting the choice locations for their farms upon lands subject to inundation, were compelled to resort to levees as the simplest and cheapest device for self-preservation. This manifest remedy being innate with all riparian owners, has caused a rapid extension of such protective works as the settlements along the river increased, so that by 1858 it was reported that there was practically a continuous line of levees from Cape Girardeau, Mo., to New Orleans, having an average height of 4 feet. This system, however, proved wholly insufficient for the flood of that year which lasted 199 days, the longest time on record, and covered the whole valley for distances of from 50 to 100 miles to depths averaging 12 feet. In 1823 the levees were only a foot or so high; in 1851 they were raised 5 feet high; in 1859 they were raised 7 feet high, and have been raised and enlarged to meet the requirements of each succeeding high flood which overtopped them until they now average nearly 20 feet.

A Board of U. S. Engineers reported in 1875 that the breaks of the previous year were too numerous to mention. Their total width was 130 miles, and it was added that if the levees do not break the water will run over the tops of them. "The levees are under grade from 6 to 7 feet from

Cairo to New Orleans." This was after 4 feet had been added to the levees of 1858. In 1882 the break at Illaworra, La., in a levee 20 feet high caused damages to the extent of $23,000,000, and it was stated that two or three such breaks will overflow more country than thirty when the levees were from 4 to 6 feet high.*

With a firm faith in the efficacy of an earthen dam to protect and reclaim their farms, and with no knowledge of the various other resources available for the preservation of their lives and property, the riparian dwellers along the lower river are urgent advocates of the continuation of the levee system and instruct their representatives to vote accordingly. Hence, it is that no other systematic effort has been made to modify or improve the conditions inherent to this perennial system of defence—a system which from the very nature of the forces to which it is exposed can never be regarded as complete because of the constantly caving banks which carry with them their superimposed levees.

The efforts to confine the river to a fixed channel by revetting its banks has been discontinued because of the enormous expense and unsatisfactory results, and recourse is had to dredging for relief at low water. But this is not always available, as is instanced by the recent imprisonment of the Monitor Arkansas, near St. Genevieve, Mo., just after the early spring flood had passed out, when it was expected that she might be thrown out of commission for many months or until dredges could be used to open an 11-foot channel to deep water. The Missouri flood, however, released her before the dredges were available.

Physical Elements.—It is a fundamental principle of hydromechanics that *if the capacity for outflow be made greater than that for inflow there can be no overflow*, and yet there are intelligent advocates of levees who seem to be so wedded to the idea that all the water must be confined to the trunk of the river, or be under the control of levees along the banks, that they deny the applicability of the principle to this stream and insist that the more water the more the velocity, and the more the work of scour. But it should be added that if the water is poured in at the upper end faster than it can be voided at the mouth, it must be dammed back and its velocity be retarded by the impounding of the volume, and hence the sediment will be dropped in the stream and the crossing bars be raised because of the higher stages of the flood. This is abundantly proven on a large scale at the South Pass, where the two jetties (levees) retard the flow and have filled up along the entire reach of the river above for 12 miles, so that where at one time the depths were over 70 feet, they are now less than 30, and yet it is asserted that similar congestions in the main trunk do not cause the bed to rise, because careful surveys made at a few years' interval appear to show no such deposits. The question of the rate of sedimentation will be considered later if time permits.

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* See Document No. 123 Senate, Fifty-fifth Congress, First Session, 1897.

MAP OF THE MISSISSIPPI DRAINAGE SYSTEM

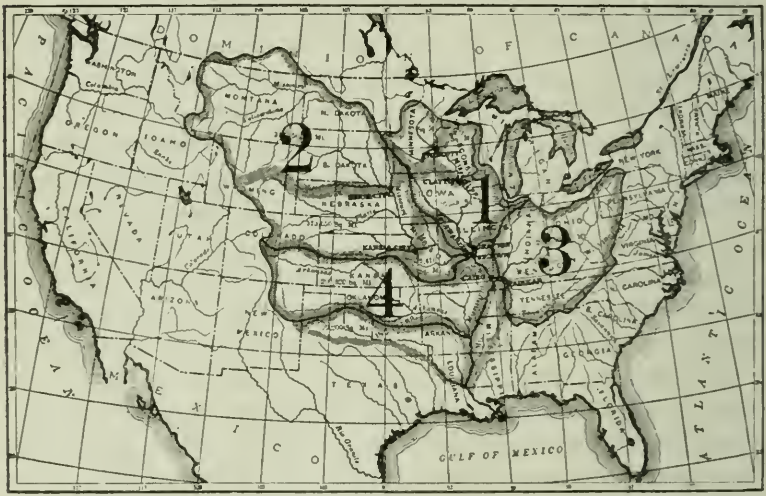

FIG. 1.

Physical.—To understand the problem fully it is important to look briefly at some of the elements which affect the movements in the drainage basin, taken as a whole. These are its form, area, relief, slopes, rainfall, runoff, vegetation, temperatures, etc., most of which may be concisely presented in the form of a tabular statement, as follows:

PHYSICS OF DRAINAGE BASINS OF MISSISSIPPI VALLEY..

Name.	Area.	Annual Rain.	Total c f. of Precipitation.	Run Off, c.f.	Mean Disc.	Ratio.	Elevation at Source.	Length.	Elevation at	
Name	Sq. mls.	in.			per c.f.		feet.	miles	feet	miles
Up. Miss. . .	169,000	35 2	13,800,000,000,000	3,300,000,000,000	105,000	0·24	1,689	1,330	St. Paul, 670	658
Missouri . .	518,000	20 9	25,200,000,000,000	3,780,000,000,000	120,000	0·15	6,800	2,908	Mouth, 281	—
Ohio R. . .	214,000	41·5	20,700,000,000,000	5,000,000,000,000	158,000	0·24	1,649	1,265	Pitts., 699 Mouth, 275	975
Arkansas .	189,000	29·3	13,000,000,000,000	2,000,000,000,000	63,000	0 15	10,000	1,514	Mouth, 162	—
Red	97,000	39·0	8,000,000,000,000	1,800,000,000,000	57,000	0·20	2,450	1 210	Mouth, 54	—
Yazoo . . .	13,000	46·3	1,500,000,000,000	1,300,000,000,000	43,000	0·90	210	500	Mouth, 103	—
St. Francis and others	10,500	41.1	1,100,000,000,000	990,000,000,000	31,000	0·90	1,150	380	Mouth, 200	—
Small tributaries	32,400	—	3,600,000,000,000	3,240,000,000,000	—	—	—	—	—	—
Lower Miss.	—	—	—	—	675,000	0·25	416*	1,286*	Mouth, 0	—
	1,242,900		87,700,000,000,000	21 410,000,000,000						

* High water at mouth of Missouri River.

In connection with this table it is well to give the areas of the natural receiving basins which are subject to inundation by the unrestrained waters overflowing their banks:

AREAS OF NATURAL SEDIMENT BASINS.

	Sq. Miles.
St. Francis, on west bank	6,706
White River " " "	956
Tensas " " "	5,370
Atchafalaya " " "	8,109
Yazoo, on east bank	6 648
Ponchartrain, on east bank	2,001

Total area, 29,790 square miles, which is about 0·024 per cent. of the entire basin. If the entire discharge be confined between levees from Cairo to the mouth of the Red River, where the outlets begin, the area would be reduced to only about 4,500 square miles, or 15 per cent., thus leaving say 85 per cent. from which the river water is intended to be excluded and the natural process of fertilization and sedimentation is cut off. As a large portion of this is swamp land which cannot be drained, because of its level being below that of the river, it would seem to be unwise thus to deflect the only means by which it might have been gradually elevated and made habitable. Moreover, the area included between the existing levees is far from being that ideal trough which should be provided for the maintenance of a uniform flow, so necessary to the creation of a navigable channel, as will presently appear.

From the above table it will be seen that if the floods from all the tributaries were simultaneous the lower river channel between levees would be entirely inadequate and the country would be uninhabitable; but, fortunately, in the Divine economy, the rigid hand of the Ice King seals up the more remote and higher sources of the western floods until those from the Appalachian chain have in large part passed down to the sea.

It is a well-known fact that the slopes of the streams diminish as they approach their mouths and that the sediment which they transport grows smaller in size. It must, therefore, follow that the coarser gravels and shingle deposited in the higher reaches cannot be carried throughout the entire length of the stream and be dumped into the Gulf. It must, consequently, remain in the bed of the river, causing it to rise; and yet it is claimed that such is not the case, for if the bed rises the height of the floods must increase proportionately and the levees also. Upon this denial of bed elevation depends the argument in support of levees, whose advocates maintain that they control the floods and cause compensation for the increased volume by deepening. Careful surveys have been made over long stretches of the trunk of the river, but it is conceded that they prove nothing, while the increasing height of the floods and levees point strongly to a confirmation of the opinion that the bed is silting up. It certainly seems rational that if there is an increasing scour in the higher reaches, that the lesser slopes at the mouth, which are at times negative, would arrest the movement and thus obstruct the discharge and raise the flood-plane. This view is confirmed by the composite cross-sections just issued by the Mississippi River Commission, showing deposit in the low-water areas and caving of banks above that stage.

Rate of Sedimentation.—It has been said by them of old time, that "All the rivers run to the sea, yet the sea is not full; unto the place from whence the rivers come, thither they return again." While this is true of the waters of the rivers it is not true of the sediment which they carry. The millions of tons of rain, aided by the frost and winds, denude the mountain fastness, so rich in mineral and fertilizing elements, and feed it to the great hydraulic conveyors which transport it to and deposit it upon these garden spots of the earth, built up of the material supplied by the mountains.

It is stated that since the mouth of the river was at Commerce, just above the Ohio, the deposits have covered some 40,000 square miles, which have been reclaimed from the Gulf and elevated to a height of 285 feet at Cairo, sloping both laterally and longitudinally, so that the river runs on the ridge which it has built up from the bed of the Gulf.

This feature of alluvial rivers is manifest by a glance at the delta, which so clearly exhibits the process of land structure by the long, tapering salients which carry the several arms of the stream far into the Gulf, instead of permitting it to escape down the shortest and steepest slope to the level of the sea. A cross-section of the river also shows the elevation of the banks to be high est along the borders of the stream, and that it falls away in the distance at the average rate of about 3 or 4 feet in each mile, so that the overflow drainage is away from the river and into the bayous and swamps which are its natural sedimentation basins.

It has been estimated that the volume of sediment carried into the Gulf each year varies from 250,000,000 to 278,000,000 cubic yards, but it is also stated that the banks are constantly caving at the rate of about 9 acres per mile of river and that their average height is from 30 to 45 feet, which would contribute about 332,000,000 cubic yards to the bed of the stream, independently of the amount fed by the tributaries, which is no doubt much more, so that the net amount of sediment left in the bed would exceed that deposited in the Gulf, if it be prevented from spreading beyond the bank by levees. Hence it must follow that unless the ejecta are equal to the injecta the excess must contribute to elevation. This may readily be accepted as a fact when it is seen that a single flood may cause deposits on a level amounting to from 6 to 12 inches of mud.

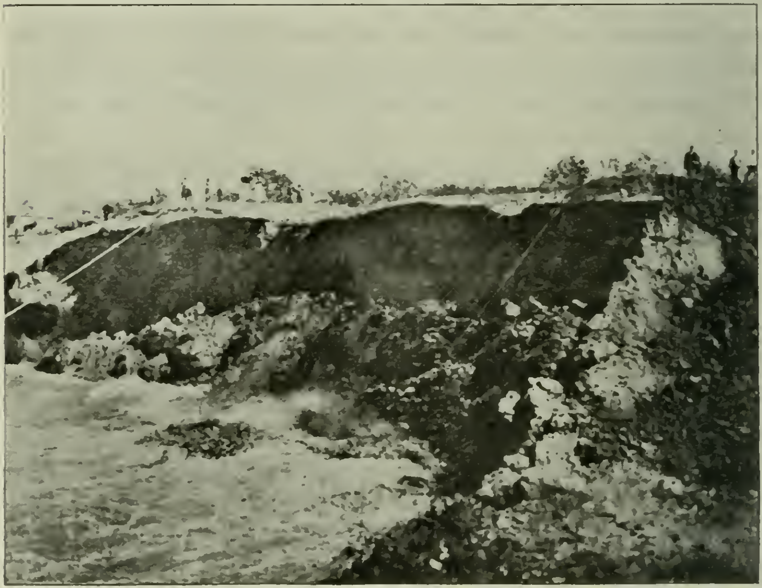

FIG. 2.—Banks in the act of caving.

It is well known that any alternations of velocity will cause corresponding scour or deposit, and that such alternations are caused by variations of cross-section such as are produced by the great fluctuations in the distances between the levees and banks, ranging, as they do, from less than 2 miles to more than 20, so that large areas of deposit are created in the bed of the river, covering in some cases more than 100 square miles.

(See the chart of the Third Engineer District.)

HYDROMECHANICS.—OBSTACLES TO DISCHARGE DURING FLOODS.

Benefit of Outlets.—To dam a river, in whole or in part, restricts its flow and invites deposits. It is immaterial whether the obstruction be composed of stone, wood, earth, silt, water or air; or what its form or position, so long as it encroaches upon the natural waterway.

During the June flood at St. Louis, after the river had begun to fall, the wind veered and raised it over half a foot, causing a breach in the banks and a large additional loss of property.

In 1860 it raised the level of the river near New Orleans 4·6 feet in two hours, inflicting great damage. The level of Lake Borgne was raised 11 feet at the same time. On September 8, 1900, a hurricane swept over the city of Galveston, raising the height of the water 16 feet above the mean Gulf level, and destroyed more than 5,000 lives. Numerous instances might be cited where the winds have operated to impound waters and cause loss of life and property. In a similar manner the waters of a tributary stream in flood have checked those of the main trunk, or the reverse, and caused overflows and consequent loss. Two or more tributaries discharging simultaneously above an engorged reach, must also result in an overflow. These contractions, which are so numerous along the lower Mississippi, operate to retard the flow above them, causing deposits, not scour. It is mainly when the waters of a basin are permitted to discharge freely into a lower level, or under a "head," that scour takes place, hence the use of tidal sluicing basins in many countries to maintain short channels over ocean bars, by flushing at low water. Hence, also, the scouring effects observable in consequence of crevasses in levees, which instead of injuring the lower reaches of the main river are found to improve them.

The Gulf itself is a water dam which, by its inertia, checks the discharge of the river and deposits its silt across the path of the currents, and no amount of jetty extension can change the operation of this law. Moreover, the salt water being heavier than the fresh, buoys the latter up and causes it to float seaward on an ascending gradient so that the limit of the depth of the scour of fresh water is restricted to about 12 feet at a distance of 4 miles from the bank. Temporary modifications may be effected by rapid extensions of the bank, in the form of jetties, but these contractions merely increase the resistance to the discharge, and by raising the flood plane cause new breaches in the low banks above, as at "The Jump and Cubitts Gap." They do not, therefore, relieve the river, but invite further disaster and new outlets.

These commonplace suggestions are prompted by the oft repeated remarks that "the greatest good will be derived from the complete control of the floods between levees," which, it is added, "involves no dangers," and that "it is an error to allow large quantities to escape, hence the outlet propaganda is a 'plague' and is condemned by such high authorities as Generals Humphreys and Abbot."

It may be interesting to state the correct report of these eminent authorities in this connection, as it has been so erroneously quoted and misused to sustain the idea that levees are the sole protection from floods. They say, on page 394, "Physics and Hydraulics of the Mississippi:"

"The facts above cited establish that there is no evidence that any filling up of the river bed ever did occur in consequence of a high-water outlet; and, moreover, that it is impossible that it ever should occur, either from the deposition of sedimentary matter held in suspension or from the accumulation of material drifting along the bottom. The conclusion is then inevitable, that *so far as the river itself is concerned, they * are of great utility.* Few practical problems admit of so positive a solution."

In its application, however, they found some practical difficulties from the fear that Lake Ponchartrain would be filled up in a long period of time. These views as to the utility of outlets are fully sustained by the description of the outlet reach of the river extending from the mouth of the Red River to the Gulf, as reported by a member of the

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* Outlets.

Mississippi River Commission, who says: "In this portion of the river the channel is narrow, averaging about a half mile in width and the depth sometimes exceeds 200 feet. Bank erosion is slight as compared with the fourth reach, sand bars as obstructions to navigation are almost unknown, and neither contraction works nor dredging are required. Here, nature has constructed an ideal channel with sufficient depths at all times for the largest sea-going craft. For nearly the entire length the water is confined to a single channel down to the Head of the Passes, there being but two island, Profit and Bayou Goula, in the entire reach.

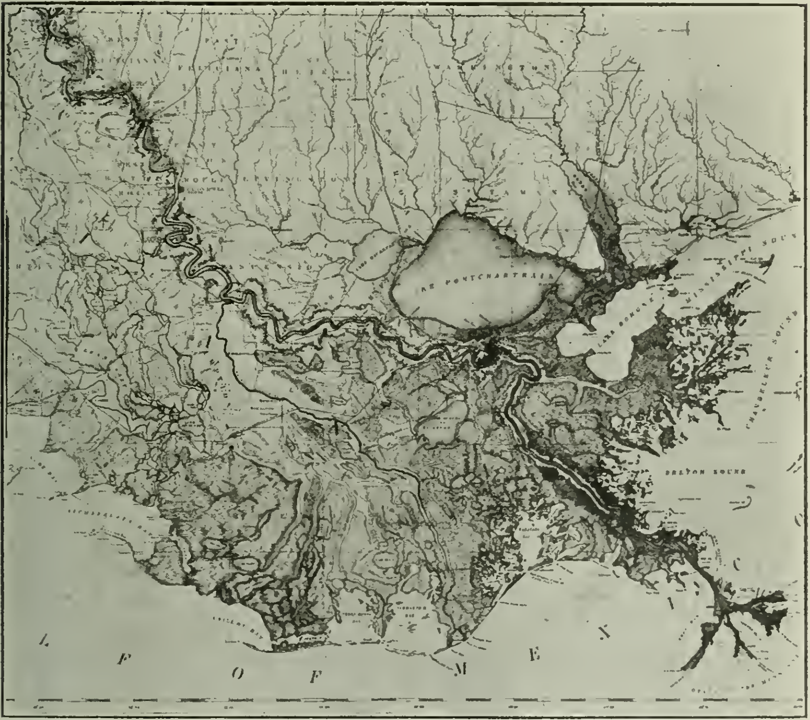
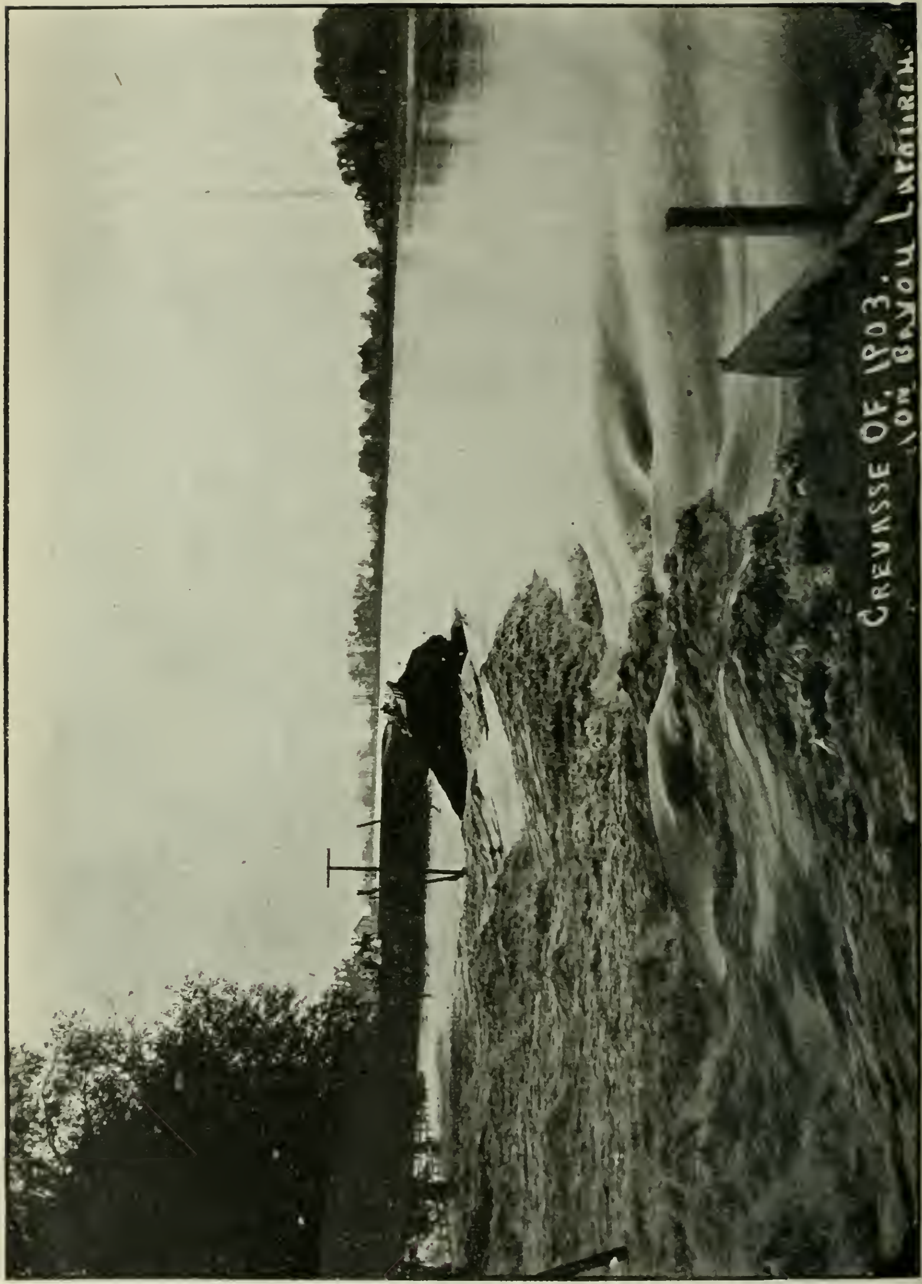


FIG. 3.—The outlet section from Red River to the Gulf, showing parallelism of the levees.

"As the upper limit of the reach at low water is less than 2 feet above mean Gulf level, it often happens that the tidal effect is noticeable throughout its entire length.


CREVASSE OF, 1903.
ON BAYOU LAFOURCH.

The Red River is the only tributary in the fifth reach which adds to the volume of the main stream.

"There are several outlets through which the waters of the river can flow to the Gulf of Mexico. Some have been closed by levees, as Manchac and Plaquemine Bayous. The Achafalaya, La Fourche, Collet, The Jump and Cubitts are still open, but are gradually filling up with sediments. . . The extreme oscillation in stage recorded up to the present time at New Orleans is 20·7 feet."

Thus nature has demonstrated the great superiority of this stretch of river where the fluctuations are less than one half those of the higher reaches, the channel far more permanent, the banks stable and the protection far superior, because of the safety-valves afforded by the various outlets, which unfortunately are slowly filling as the sediment is left in them from the overflowing waters, thus raising their beds and reducing their capacity. The effect of this congestion was forcibly illustrated by the crevasses which occurred this year on the Bayou La Fourche, in front of Hon. W. E. Howell's plantation, as shown in the accompanying illustration, taken from the *Louisiana Planter* of June 20, 1903. If man does not provide the necessary outlets for the rapid discharge of the floods, nature seeks relief where it is least expected and without warning, carrying ruin in her wake.

The increase in stage due to the extension and elevation of levees by attempting to "control" the entire floods is shown forcibly from the gauge record at Carrolton since 1828, when it registered 14·85 feet; in 1851, it was 15·05; in 1874, 15·35; in 1897, 18·72 and in 1903, 19·05.

Serious Defects of the Levees.—From the very crude manner in which the levees were developed, by localities and individual planters, it was not practicable at first to construct such a system as is desired to train the river in its onward course to the sea. These fragmentary low levees were gradually connected and built up along former lines until there resulted an angular alignment of great variability of cross-section between banks or bluffs causing serious contractions to throttle the floods and impound the high waters in the bed of the stream, thus creating pools and chutes which are so much to be avoided in the maintenance of a navigable channel. For example, the reach extending from the mouth of the Arkansas River to Vicksburg, at the mouth of the Yazoo basin, may be taken as a type. Here it is seen that at the outlet of the Arkansas the distance between banks is about 17 miles, while at Arkansas City it is contracted to less than 2 miles by a salient line of levees which might apparently have been located a few miles farther back, thus saving about 5 miles of levee work and affording a much better discharge. Again, at Greenville a pool exists 8 miles wide by about 12 long at high water, with a similar gorge below it which has caused serious crevasses in this section. So throughout the 213 miles in this district, these features recur at frequent intervals, the worst being at Vicksburg, where the gorge creates the backwater which inundates the lower Yazoo district. It is evident that the relief must come, not by beginning the rectification of the levee alignment at the top, thus pouring more flood water into the lower pools, but by opening the throats of these congested sections from the mouth up and letting the water out more rapidly, thus creating a scour which will deepen the bed and lower the flood, as in numerous foreign rivers. This would reduce the cost of maintaining the levees by diminishing their length and give a better channel with less cost for dredging. The land thus forfeited would be more than gained by the immunity from inundation of the back country and the drainage of other territory.

Discharge Capacity.—To determine the effect of bends upon the discharge of a conduit, some experiments have been made by the writer on tubes of different diameters, two of which represented the low-water channel, one being flexed to conform to its convolutions and the other straight to represent the developed equivalent length, and the time required to pass a given volume of water through them, under a constant head, was noted. From these experiments it was found that the bent tube had a capacity of only 17 per cent. of its equivalent straight tube. Similar tests on the two larger, high-water tubes showed that the one repre-

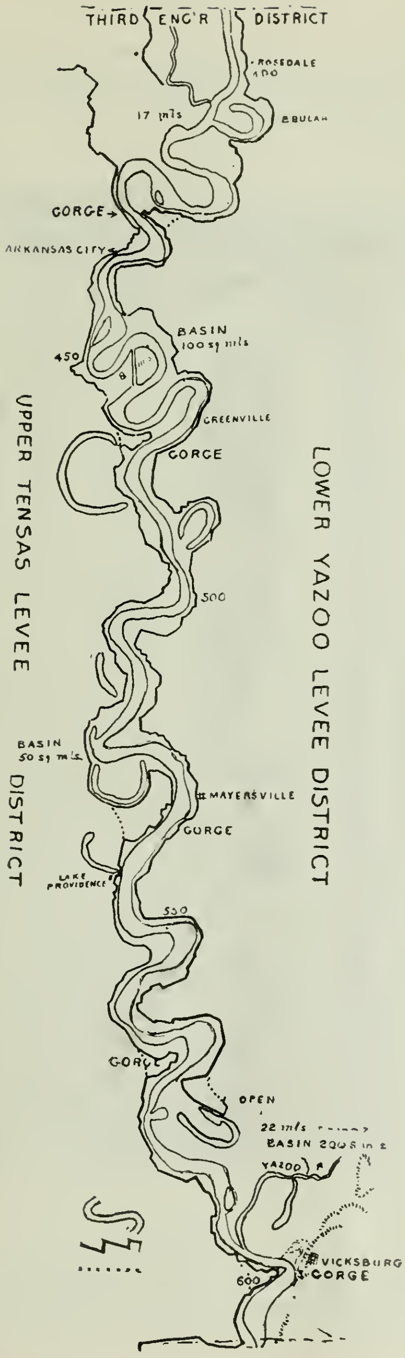
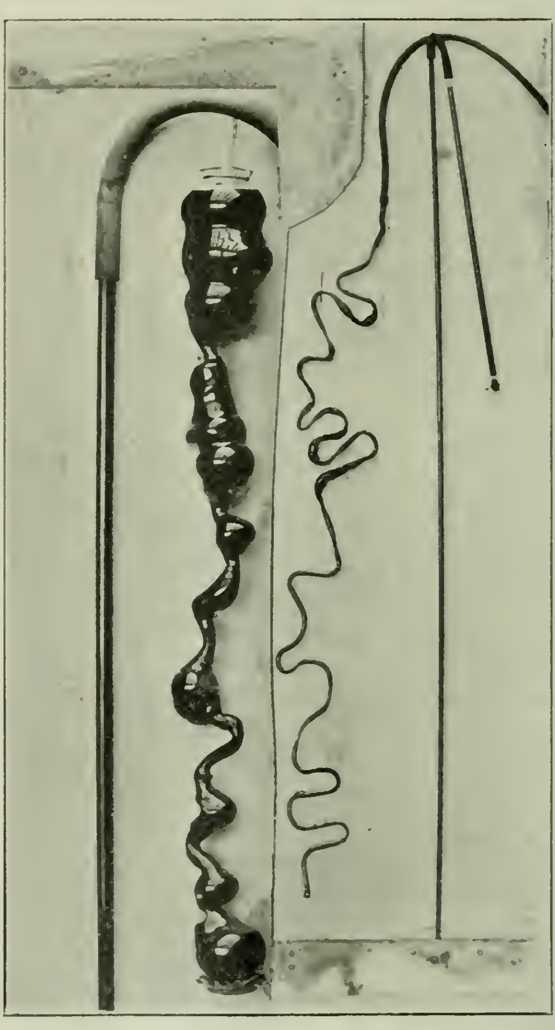

THIRD ENG'R DISTRICT
ROSEDALE
400
17 mls
BEULAH
GORGE
ARKANSAS CITY
BASIN
100 sq mls
450
8 mls
GREENVILLE
GORGE
UPPER TENSAS LEVEE DISTRICT
LOWER YAZOO LEVEE DISTRICT
500
BASIN
50 sq mls
MAYERSVILLE
GORGE
LAKE PROVIDENCE
550
GORGE
OPEN
22 mls
BASIN 200 S m
YAZOO R
VICKSBURG
GORGE
600

FIG. 5.

senting the distortions of the levees had a capacity of but 44 per cent. of the corresponding straight tube. In this series of experiments the pools would fill more rapidly than



High-water channels. Low-water channels.

FIG. 6.

the gorges could pass the current, causing overflows, as in a state of nature, and impressing the necessity of a uniformly canalized channel.

Relief Measures.—The resultant of all the experience of the works done on the river shows that there are two distinct problems to be solved. The one relates to the reclamation and protection of the arable lands as a source of revenue and supply, the other to the improvement of the channel of the river as a means of cheap distribution; and the methods now applied to meet these requirements are the attempt to confine the entire flood to the irregular sections between high levees and to improve the low-water stages by the removal of the bars built by the floods, by dredging channels, which are obliterated at the next high water.

Under these circumstances it would seem that the problem is still an open one and that there is room for improvement, and although the engineering profession has no direct control, it may perhaps make suggestions in the interests of humanity and for the betterment of the channel, which, if carried out, may result in less loss and risk to life and property. These remedial measures must evidently be directed towards the prevention of simultaneous floods and accumulation of large volumes of water, which must be carried in a congested conduit for long distances before it can find relief, and therefore no single system will fulfil these requirements but a combination of impounding reservoirs on the tributaries, especially of the western sections, where they may be utilized for irrigation; reforestation of the arid regions; levees with a readjusted alignment and low-weirs at suitable points for spill-ways, to be connected with large subsiding reservoirs in the swampy bayous; and, finally, by the removal of the bars at the delta and opening of all the available and possible outlets to permit of a rapid voiding of the excess of the floods. By such a combination it is believed the navigable channel will be deepened and be made more permanent, the flood plane will be lowered and less arable land be inundated, the height of the levees will not have to be constantly increased, the discharge will be retained for a longer period in the lateral basins, from which it may be fed to the main trunk to sustain a nearly uniform stage and water be stored for irrigation, which is already becoming a necessity in the lower valley because of the exclusion of the flood waters by the levees.

The practicability of the lateral basin system as an auxiliary has been carefully considered and ably presented by James A. Seddon, C. E., for years engaged on the hydraulics of the Missouri and Mississippi rivers. He has shown, by a series of hydrographs, the possibility of so regulating the flow of the river as to reduce the flood heights from its present extreme range of 50 feet to about 25 feet, by the construction of six reservoirs along the back-waters of the St. Francis basin, where the fall is about 120 feet from Cairo to Helena. This work is estimated to cost $32,000,000, including land damages and auxiliary works, and can be built in ten years.

The time is too limited to do this subject justice, but in view of the impending danger from the augmented volume, it is never too late to call attention to the possibilities of relief, which is all that the engineering profession can do until the people of the valley awaken to the necessity of their application and demand a change of plan.

SCARCITY OF LUMBER.

Recent forest fires in the timber belt of Maine have devastated large tracts of land, hundreds of square miles, which cannot be replaced in many years, and the freshets in the Mississippi have carried away millions of feet of logs, which will never be recovered. A writer in the *Sun* says that more lumber has been destroyed this season by misadventure than manufacturers can cut in a year. These casualties and the natural consumption tend to make commercial timber scarce and high, and those who contemplate building where wood is required are advised to do so immediately, as it will be a long time before it can again be had at present rates. Southern lumbermen who furnish yellow pine are ninety days behind their orders, and the price has been advanced on some grades $2 per 1,000 feet. The writer above quoted says that forestry is a very slow remedy for renewal of standing wood, for it takes thirty to forty years to grow trees to 24 inches diameter, which is the size demanded for boards. The supply of hemlock in the immediate vicinity of this market has been exhausted, and people who require it are compelled to buy 300 miles away. There is practically no wood of this kind left in Pennsylvania, unless it may be in the western part of the State, and when this is cut and consumed it will be necessary to use other varieties. White pine, oak and cypress have advanced during the year from $6 to $14 per 1,000 feet. The increase in population annually reaches large figures, and the consumption of lumber must keep pace with it, but from the facts quoted there will be a shrinkage instead of a surplus over former years. In this condition of affairs the importation of foreign woods from our new possessions should receive a decided impulse.

The Induction Motor and Its Engineering Capabilities.*

[*A Thesis Presented to the University Faculty of Cornell University for the Degree of Doctor of Philosophy.*]

By George L. Hoxie.

(*Continued from p. 214.*)

Part II.

OPERATION OF THE MOTOR.

Qualitative.—We have seen that the primary currents produce a regular magnetic field, and that when the secondary carries no current, sensibly all of this field enters the secondary structure, and surrounds the secondary conductors.

If the secondary be stationary, an E. M. F. will be induced in each secondary bar, that is practically equal to the counter E.M.F. which the same flux produces in each primary conductor. Let the secondary bars be joined together at each end of the motor by rings of conducting material, but having a very high resistance. Since there are six poles with flux entering, and six with flux leaving, the secondary, there will be six regions on the rotor where secondary current will flow in one direction, and six regions where the currents flow in the opposite direction.

The developed diagram for the secondary current circuits is found in *Fig. 14.* The ladder-shaped figure represents thirty-five of the secondary bars, and the end rings which complete the circuits, and make possible the flow of current. It will be remembered that the E.M.F. induced in a single primary conductor was such as would be produced by a sine wave of flux, crossing it with a uniform velocity. If the total flux crosses into the secondary, an equal E.M.F. will be induced in each secondary conductor, as long as it remains stationary. Above the ladder in *Fig. 14* is drawn a sine wave which may represent an equivalent flux wave for this motor. It is drawn in the proper relation to the secondary conductors. A uniform progression of such a wave would generate E.M.F.'s in the secondary conductors, the amount and direction of which are represented by the arrows of *Fig. 14.*

We have assumed that the end rings joining the secondary conductors together, have a very high resistance. Let us further assume (incorrectly) that this resistance is the same for each current path. Then small currents will flow in the secondary, and these currents will be in phase with, and proportional to, the E.M.F.'s which establish them, and the currents and E.M.F.'s may be represented by the same arrows.

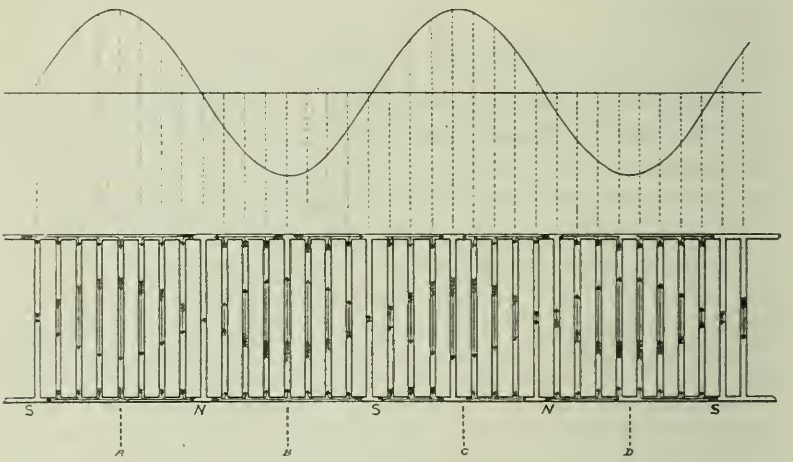


Fig. 14.

The division of the currents into current groups, or circuits, is indicated by the dotted lines *A*, *B*, *C*, and *D*, in *Fig. 14.* If such current circuits were present alone in the machine, they would produce magnetic circuits, linked with themselves, and having maximum densities at the points *N*, *S*, etc., of the figure. That is, the secondary currents would tend to set up a field 90° behind the field due to the primary. The distribution of such a field would have a sine form. It could only be small as compared with the primary field, since we have assumed a large secondary resistance, and a small current, in order that current and E.M.F. may be in phase.

The combination of secondary and primary fields would give a resultant field slightly shifted back from the position that we have assumed, and would introduce some minor changes in the above discussion, which we are not yet ready to consider.

Torque.—It may be noticed in *Fig. 14* that the maximum currents lie directly under the maximum generating E.M.F.'s. If the conductors lay on the surface of the secondary, they would experience a force urging them from right to left. All the forces present would be in the same direction, and the secondary structure, if free to do so, would revolve.

In the actual motor, the secondary conductors lie in slots and probably experience little or no force. The resultant effect is, however, quite the same, since the actual mechanical force is in any case due to the tension of flux which is distorted by the current. This distortion, in the case of embedded conductors, is still produced in about the same way, but the tension is transferred to the secondary teeth, since the flux mainly enters them.

Secondary With Little Resistance.—Quite a different state of affairs is found if the secondary conducting circuits contain little resistance. Imagine the secondary to be stationary. The secondary E.M.F. is produced as before. The currents flowing are mainly limited by self-induction, and will therefore lag nearly 90° behind the E.M.F.'s producing them, or will lie 90° to the right of the E.M.F. positions of *Fig. 14*. This brings the M.M.F. of the secondary directly opposed to the M.M.F. of the primary. The flux surrounding the primary conductors must remain nearly the same. The primary current must therefore increase greatly,—so greatly that a considerable part of the primary flux, prevented from entering the secondary, leaks along the air gap, and crosses between the primary teeth near their ends.

The torque present is nearly as much in one direction as the other, and the net turning force on the secondary structure is very small.

Moderate Resistance in End Rings.—As these motors are usually constructed, the end rings are composed of an alloy having a considerably higher resistance than copper. The secondary currents, with the motor stationary, are partly limited by self-induction, and partly by resistance. The secondary currents lag behind the E.M.F.'s that produce them, but the lag is considerably less than 90°. (The exact angle of lag depends of course upon the ratio of self-inductive reactance to resistance.) The torque is considerable, and the primary current is smaller than without the high resistance end rings. Since some current paths include more of the end rings than others, the currents are no longer proportional to the E.M.F.'s, and the secondary flux wave taken alone is somewhat more pointed than a sine wave.

Secondary Revolving.—Since the pull on the secondary, or rotor, is in the direction in which the magnetic field travels, its rotation will be in the same direction. In general the rotor travels somewhat slower than the flux. This means that the relative speed of the flux, referred to the secondary conductors, is decreased, and the induced E.M.F., and the frequency, is less. The secondary resistance is unchanged, but its inductive reactance, which is proportional to the frequency, is lessened. The secondary currents are in a better position for the production of torque, and are less in opposition to the primary currents, when the motor is running than when it is standing still. The magnetic leakage for a given secondary current is considerably lessened for the same reason.

Slip.—The field, or the equivalent field, due to the primary currents, revolves at a rate dependent upon the frequency of the primary impressed pressure.

If the rotor is stationary, the secondary frequency is equal to the primary frequency. If the rotor is revolving at the same rate as the flux, *i. e.*, at "synchronous speed," the secondary frequency is zero. The speed of the rotor is frequently measured in "per cent. of synchronism." The difference between this number and 100 is known as the "per cent. of slip," or the "slip." The secondary frequency is the product of this slip, and the primary frequency.

Relations of Torque, Current and Speed.—If no self-induction is present in the secondary—a case which may be represented by *Fig. 14*—the torque depends solely upon the secondary current, and therefore upon the secondary E.M.F., or inversely upon the slip, no leakage being present when self-induction is absent. Such a motor would be a practical impossibility, but would have a straight torque speed characteristic, running from zero torque and synchronous speed, to maximum torque, and zero speed. The power-speed curve would reach a maximum at half-speed, and would be zero at synchronous speed, and at zero speed, the two sides of this curve being symmetrical.

It is of course impossible to approximate, in the actual motor, to a condition of no self-induction, or even to a very small self-induction. It is possible, however, to accomplish about the same results, by increasing the secondary resistance, thereby making its self-induction relatively less important. Such a motor will have a torque decreasing with an increase in speed, or conversely, the motor will vary in speed with varying demands upon it for torque. In other words, it is to some extent a variable speed motor. Owing to the secondary resistance, considerable amounts of energy are lost in heating the secondary conductors and the efficiency of the motor is thereby lowered.

If the resistance of a motor secondary is very low, its inductive reactance is large in comparison, except for speeds so near synchronism that the secondary frequency is only a small fraction of that of the primary. At all other speeds the secondary currents lag greatly behind the induced secondary E.M.F.'s, and, as previously shown, the torque is small. At the speeds near synchronism the slip is small, and the secondary E.M.F. is small, but as the resistance is low, considerable secondary currents may be present. Such a motor will exert any torque between zero and its maximum, with a decrease in speed of only a few per cent. It is therefore practically a constant speed motor.

The starting torque of the variable speed motor is high, while that of the constant speed motor is low. The secondary current of the former varies with the torque. The secondary current of the latter varies with the torque, and power, up to about maximum torque and remains fairly constant after that, while the speed of the motor is reduced.

Primary Leakage Wave.—The primary leakage flux must travel along the air gap through a region of high reluctance, and practically constant permeability. The paths of this flux should extend from tooth to tooth, as for the useful flux, *i. e.*, in *Fig. 7*, leakage would be found between teeth 6–8 : 5–9 : 4–10, etc. Calling a distance along the air gap occupied by one tooth and one slot as representing one unit of reluctance, we would have in the motor previously studied:

Path No.	Reluctance units.
1	12
2	10
3	8
4	6
5	4
6	2

Fig. 15 gives the corresponding leakage waves. They are derived from *Fig. 4*, by dividing each ordinate by the corresponding reluctance unit. It should be noted that the primary leakage flux is in a constant phase position with respect to the primary current. That is, its position is not altered by the secondary currents, and the primary impressed pressure that is consumed by the leakage counter E.M.F., is always 90° in advance of the primary current. This means that a large primary leakage is accompanied by a low primary power factor.

Primary Power Factor.—When no secondary current flows, the useful primary flux is in phase with the leakage flux, or the primary counter E.M.F. is 90° behind the primary current. The primary impressed E.M.F. is mainly made up of a component balancing the counter E.M.F., and is therefore almost 90° ahead of the primary current. The power factor in this case is very low. Energy is consumed by primary resistance, and by hysteresis losses, and by eddy currents in the iron only.

In the discussion of *Fig. 14*, it was shown that the first small secondary currents set up a field 90° behind the primary field. If the two were of equal strength, the resultant would be 45° behind the *original* primary field. But as it is the *resultant* field which sets up the secondary E.M.F., a resultant field lagging 45° would give secondary E.M.F.'s (or currents, if the secondary were without self-induction) that would be 90° plus 45°, or 135° behind the original primary field, and this in turn would shift the secondary current again, and so on till a balance was reached at a point depending on the relative values of primary and secondary currents. The final resultant field would obviously lag behind the position of the original primary field, but the lag could never be as great as 90°. If the lag were 90°, the counter E.M.F. in the primary would be 180° behind the current, or the impressed E.M.F. would be in phase with the primary current—a condition where the power factor in the primary would be unity.

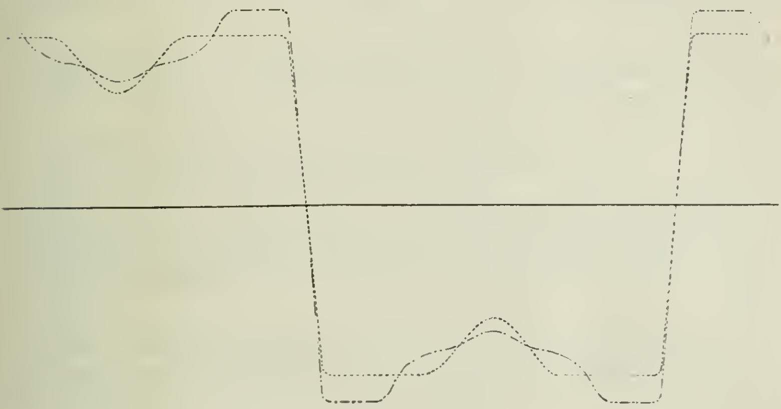


FIG. 15.

Transfer of Power Between Primary and Secondary.—The power given to the primary is transmitted to the secondary through the medium of the resultant magnetic field. The primary currents are pulling this field forward, and the secondary currents are pulling it backward, while the field itself is changing in a manner which amounts in effect to a continuous forward motion. The primary is therefore doing work, and the secondary is receiving it, or rather is passing it along as mechanical power.

When the secondary has self-induction, the secondary currents may lag up to something less than 90° behind the induced secondary E.M.F. The secondary M.M.F. may therefore be brought nearly into opposition with the resultant flux. This, as we have already seen, does not involve a transfer of power, nor does it tend to shift the resultant flux from the phase position of the primary. A large primary current is drawn at a very low power factor.

Mechanically Driven Secondary.—If the secondary be driven in the direction of normal rotation, at a speed faster than the equivalent rotating flux wave, a rather peculiar state of affairs results:

(1) The E.M.F. in the secondary conductors is reversed in direction.

(2) The reaction of the secondary M.M.F. shifts the phase of the resultant flux forward.

(3) The flux travels past the primary conductors and the currents in these pull back on it. Electrical energy is therefore produced in the primary.

(4) The secondary currents push the flux in the direction of its travel. The secondary therefore is doing mechanical work.

The induction motor, if driven mechanically at a speed beyond synchronism, becomes an induction generator. It is necessary, however, that its primary should have an initial excitation.

Two-Phase Motor.—When the primary of an induction motor is suitably wound and is excited with a two-phase current, the flux changes which occur in its magnetic circuit are very similar to those that have been studied in connection with the three-phase model. The preceding discussions will, therefore, apply without material change to the case of a two-phase machine.

Induction Motor Equations.—If Φ = flux per primary pole, and Φ_m = flux per pole that is common to primary and secondary, then, if the impressed E.M.F. wave has a sine form, the counter E.M.F. per primary conductor is,

$$E_1 = \frac{2 \cdot \Phi \cdot f}{10^8} 1{\cdot}11,$$

and the induced E.M.F. per secondary conductor is,

$$E_2 = \frac{2 \cdot \Phi_m \cdot f}{10^8} \, 1 \cdot 11 \cdot sl.$$

where (f) is the primary frequency, and (sl) is the slip in per cent. of synchronous speed.

The primary impressed E.M.F. per conductor is given by the expression,

$E = E_1$ (in phase with flux) $+ I_1R_1$ (in phase with current).

This addition must be geometrical.

The values of primary and secondary current per conductor are,

$$I_1 = \frac{E}{\sqrt{R_1^2 + X_1^2}}$$

and

$$I_2 = \frac{E_2}{\sqrt{R_2^2 + (X_2sl)^2}}$$

where I_1 and I_2 are primary and secondary currents respectively, and X_1 and (X_2sl) are primary and secondary reactances, respectively, all quantities being for one single conductor.

The mechanical power given by the primary to the secondary is represented by the product of peripheral speed times torque.

We have seen that the torque is due to a continuous forward pull of the field, the latter having been distorted backward by the secondary currents. This torque for a given conductor is directly proportional to the density of the field and to the amount of the current. Such a force for the given conductor in air would be given by the expression,

$$F = B \cdot l \cdot I',$$

all quantities being in c. g. s. units.

The power expended is proportional to the force, and to the velocity of the conductors. An expression for the power per secondary conductor would therefore be,

$$P = Fv = B \cdot l \cdot v \cdot I'.$$

This is equivalent to writing,

$$P = E'I',$$

where E' is an ideal E. M. F., not actually present in the secondary, but which would be induced were the magnetic field to remain stationary while the secondary revolved with the given speed.

Calling this ideal E.M.F. E_m, since it is analogous to the counter, or motor, E.M.F. which is found in a direct current motor, we may write for the mechanical power given to the secondary,

$$P = E_m I_2 \cos \theta_2,$$

and since $E_m = \frac{2 \cdot \Phi_m \cdot f}{10^8} 1.11 (1 - sl) = \frac{E_2}{sl}(1 - sl)$,

$$P = I_2 \frac{E_2}{sl} (1 - sl) \cos \theta_2, \text{ in watts,}$$

or, $$= \frac{I_2 \cdot E_2 (1 - sl)}{746 \cdot sl} \cos \theta_2, \text{ in horse-power.}$$

If (n) is the speed in revolutions per minute of the equivalent rotating field, the torque in pounds at one foot radius is,

$$T = \frac{I_2 E_2 (1 - sl)}{746 \cdot sl} \times \frac{3300}{2 \pi n} \cos \theta_2.$$

Or substituting for I_2 its value in terms of secondary resistance, and reactance, per conductor, we have the values,

$$HP = \frac{E_2^2 R_2}{R_2^2 + (X_2 \cdot sl)^2} \times \frac{1 - sl}{sl} \times \frac{1}{746}$$

$$T = \frac{E_2^2 R_2}{R_2^2 + (X_2 \cdot sl)^2} \times \frac{1 - sl}{sl} \times \frac{33000}{746 \cdot 2 \pi n}$$

The two formulæ above may be used in the design of a polyphase induction motor. It may be noted, however, that the formulæ imply a knowledge of X_2, a quantity depending upon secondary leakage, and of E_2, a quantity depending mainly upon primary leakage. The designer of induction motors would depend mainly upon the results of tests of previous machines, for data upon which to base computations of magnetic leakage. Such data is not made public, but is closely guarded by the manufacturing companies that possess it.

Motor Characteristics.—With known values for X_1, X_2, etc., one may make substitutions in the equations for horse-power and torque, for several different values of slip, and may plot the characteristic curves of the motor.

The manner in which the torque and speed relationships depend upon the ratio of secondary resistance to secondary reactance, is well indicated by the torque-speed curves of

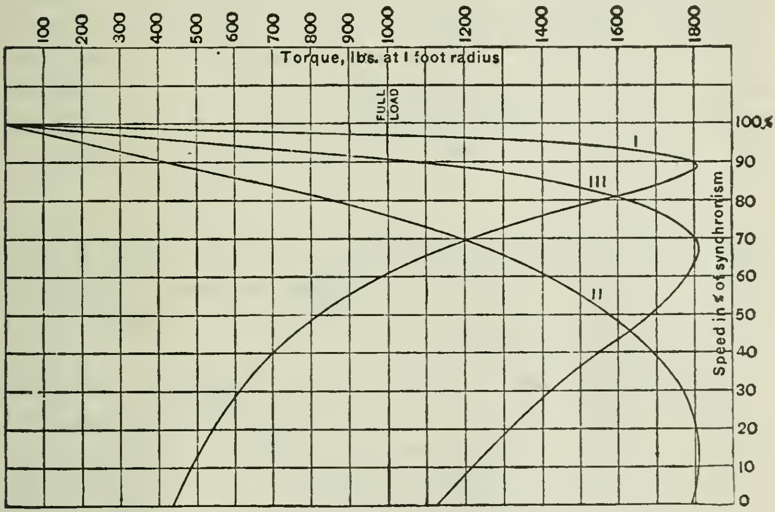


Fig. 16.

Fig. 16. These curves were given by Mr. C. P. Steinmetz (*Trans. A. I. E. E.*, Vol. II, page 35), and are for a three-phase motor, the capacity of which at full load was 100 horse-power.

Curve I is for this motor, with the lowest possible secondary resistance. The ratio of secondary reactance to resistance is large when the motor is stationary, and is zero when the motor is running at synchronous speed. With the motor stationary, therefore, the lag of the secondary current is large, and the motor torque small. As the motor speeds up, the secondary frequency decreases, and the self-inductive reactance decreases. The secondary currents are not plotted, but since the secondary impedance is mainly reactive, and varies almost directly with the slip, the secondary current will remain quite constant at the lower speeds. The torque, therefore, increases with the speed, to a maximum of 1·8 times the required torque at full load, reaching this maximum value at a slip of about 10 per cent. With higher speeds, a decrease in slip decreases the secondary E.M.F. proportionately, but the secondary reactance has been so far reduced, that the secondary current is now limited largely by resistance, and the secondary current and torque fall off quite uniformly as the speed increases, making this part of the torque-speed curve nearly straight. Curve I shows the characteristic behavior of a constant speed motor, since the speed drops only 3 per cent. at full load. The starting torque is a little less than half of that at full load.

Curve II is for the same motor with a considerable resistance added to the secondary circuit. It starts with a nearly maximum torque, but the speed between no load and full load drops 24 per cent. It, therefore, becomes to that extent a variable speed motor.

Curve III shows an intermediate condition between curves I and II. The motor starts with a good torque, and drops 9 per cent. in speed, between no load and full load.

The theoretical derivation of curves of this sort may be well illustrated graphically. For example, we will select a motor having a very low secondary resistance, and having a secondary reactance, at zero speed, six times as large. The secondary reactance is directly proportional to the frequency, and, therefore, to the slip.

In *Fig. 17*, P_2 represents the secondary resistance of this motor, and X_2 its reactance. Along the line of reactance are marked percentages of slip, from zero to 100 per cent. The horizontal distance from zero to any number represents, therefore, the secondary reactance for that slip. The secondary impedance for any slip is similarly represented by a line drawn from the top of the line P_2, to the number denoting the slip. The angle between the impedance line and the resistance line is the angle by which the secondary current lags behind its generating E.M.F., or, as it is called, the angle θ.

Using the values of slip as abscissæ, and the corresponding impedance as ordinates, the curve of secondary impedance of *Fig. 17* was constructed. It may be noted that this is very close to a straight line passing through the origin for a considerable distance. This indicates an impedance nearly proportional to the slip, over that range. We see also that between zero and 5 per cent. slip the impedance is practically constant. A curve of secondary power factors, or values of cos θ, is also drawn in *Fig. 17*.

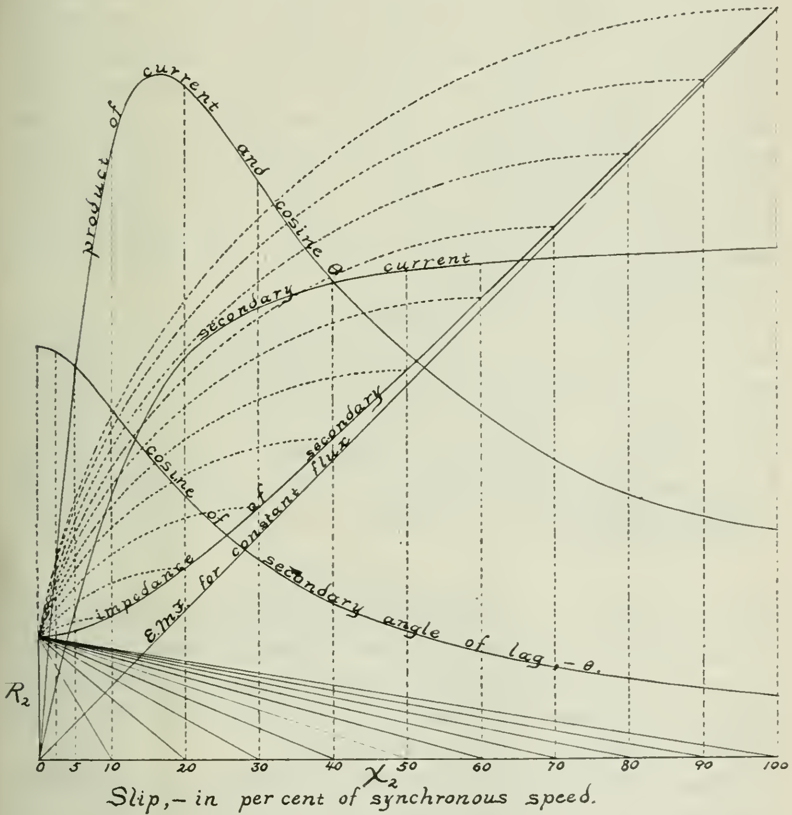


FIG. 17.

If the secondary current can be determined in any manner, the torque characteristic may be immediately drawn. The secondary current depends only upon the E.M.F. and upon the impedance. The latter quantity we know. If we assume for the present that a constant quantity of flux enters the secondary, the E.M.F. induced will depend only upon the relative speed of flux and conductors, or it will depend upon the slip. The E.M.F. curve would therefore be a straight line drawn through the origin, as in *Fig. 17*. The ordinates to the secondary current curve are then given by dividing the E.M.F. values by those for impedance. Since we are only examining the manner in which the varying quantities change with varying slips, it is unnecessary to choose a single scale for all the curves, or to determine absolutely any of the values. No vertical scale is therefore given in *Fig. 17*.

The torque upon any conductor is proportional to its current and to the density of the mutual flux in its neighborhood. It is therefore proportional to the product of these two quantities. We have assumed a sine wave distribution of the flux and a sine wave of current in each conductor. The average torque due to any conductor is, therefore, the average ordinate to the product of the two sine curves, or it is of the form,

$$T = A\,B \cos\theta,$$

where A and B are constants depending upon the quantities of current and flux and θ, is the angle of phase difference between the current and flux. Since the induced secondary E.M.F. is in phase with the flux, it follows that θ is the angle between secondary current and E.M.F.

The curve in *Fig. 17*, giving the product of secondary current and cos θ, is therefore a torque curve for this motor under the assumed conditions. The only serious error made lies in taking the mutual flux threading both primary and secondary circuits as constant. In an actual motor this flux decreases with a rise in the secondary current. The part of the total primary flux that leaks past the secondary is practically zero when the secondary does not carry current. As the secondary current increases, the primary leakage increases almost proportionally so long as the secondary power factor is near unity. A lag in the secondary current increases the leakage, so that as the secondary power factor decreases the primary leakage increases faster than does the secondary current.

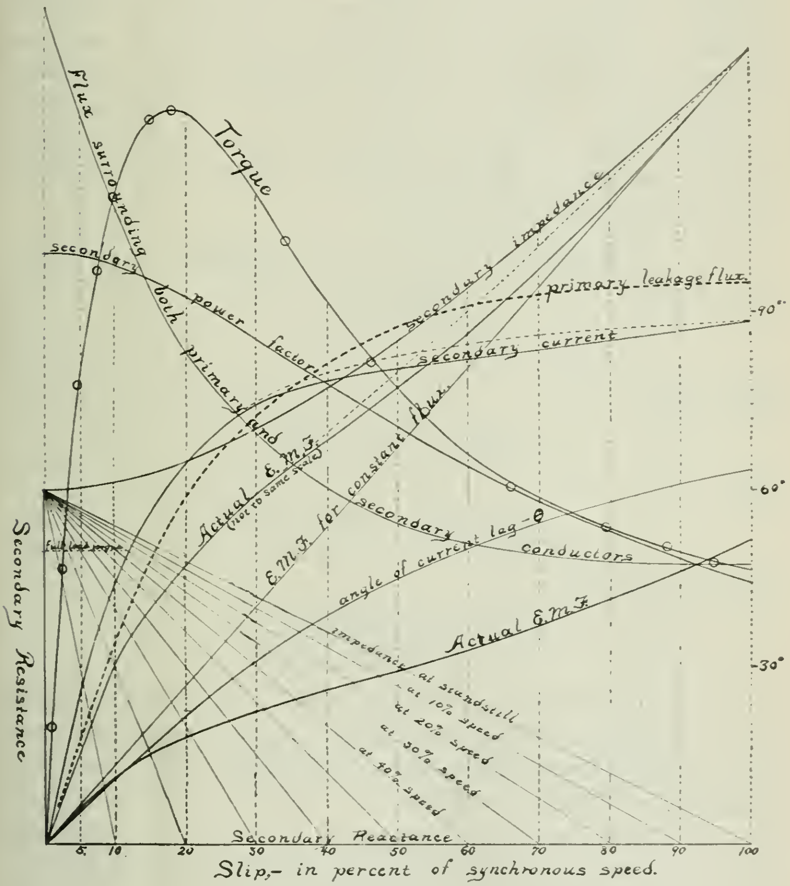


FIG. 18.

The exact relationship existing between these various items may be obtained by working backward the method used in connection with *Fig. 17*, starting with an experimental torque curve. In *Fig. 18* such a torque curve is given. The experimentally determined points on this curve are determined by circles in the figure. This curve is also one given by Mr. Steinmetz (*Trans. A. I. E. E.*, Vol. 14, page 192). The secondary of the motor on which the observations were made had a reactance, at primary frequency, equal to three times its resistance. The curves of secondary impedance, angle of lag, and power factor, were drawn as before. To make clear the method of obtaining the flux values from the torque curve, the equations will be written in a somewhat simpler form than is usual. Quantities that are proportional will be written as if equal in these equations. The form of the final result as shown graphically, is not affected by this innovation.

$$\text{Torque} = \text{current} \times \Phi_m \times \cos\theta\ .$$

$$\text{current} = \frac{E}{Z}$$

$$E = \Phi_m \times \text{slip.}$$

Therefore,

$$\text{current} = \frac{\Phi_m \times \text{slip}}{Z},$$

and

$$\text{Torque} = \frac{\Phi_m^2 \times \text{slip} \times \cos\theta}{Z}$$

Reducing, we have

$$\Phi_m = \sqrt{\frac{\text{Torque} \times Z}{\cos\ \theta \times \text{slip}}}.$$

All of the quantities in the right hand member of this equation are known, and Φ_m may therefore be determined and the curve of flux surrounding both primary and secondary conductors plotted, as in *Fig. 18*. The curve of E.M.F. is plotted as the product of flux and slip. Three E.M.F. curves are shown, one as in *Fig. 17*, and one of the actual E.M.F., drawn for purposes of comparison with this. Another curve is drawn from the same data, but choosing such a scale as brought the E.M.F. at 100 per cent. slip to the same value as the impedance. This latter curve is marked "not to same scale."

A table showing the computed figures from which these curves were drawn is given on the next page.

TABLE FOR FIG. 18.

Slip	Cos. θ	Torque	Impedance	Φ
5	·995	795	603	3108
10	·980	1140	610	2670
20	·928	1240	648	2080
30	·857	1105	790	1739
40	·780	920	768	1505
50	·707	773	846	1360
60	·640	660	935	1269
70	·580	590	1030	1228
80	·530	535	1134	1194
90	·485	495	1238	1187
100	·446	465	1345	1185

The curve of current was derived from the curves of E.M.F. and impedance. The curve of secondary current given by Mr. Steinmetz (apparently not from experiment) coincides with the curve as computed, except between the slips 40 per cent. to 90 per cent. The variations between these points is indicated in *Fig. 18* by a dotted line. This variation transferred to the E.M.F. curve is also shown by a dotted line. It is in this case such as to make a large part of the E.M.F. curve nearly straight and nearly coinciding with the curve for secondary impedance. The curve of leakage flux for the primary is derived from the curve of mutual flux, assuming that the total primary flux is constant. This curve is nearly straight and proportional to the secondary current for some distance, but increases more rapidly than the current as the secondary factor falls off.

CHARACTERISTICS AS AFFECTED BY DESIGN.

This subject will be treated under different heads, as follows:

(*a*) Effect of a wound secondary.
(*b*) Effect of a change in the number of poles.
(*e*) Effect of a change in the air gap,
(*d*) Effect of a change in the number of slots.

(*a*) *Effect of a Wound Secondary.*

Reference has previously been made to only one form of secondary winding, *i.e.*, the so-called "squirrel cage" winding. This winding is of the most universal character. It is adapted for operation with any number of poles, or for any number of phases. Currents may take any paths through it that the E.M.F.'s may indicate. In fact, the currents follow slight irregularities in the E.M.F. so closely that the current reactions damp out such irregularities almost entirely. It therefore follows that only a magnetic field of the simplest possible character, *i. e.*, approximating closely to a sine wave, may be sent through this secondary when there is relative motion between the secondary and the field. The squirrel cage secondary winding has, therefore, many exceedingly desirable qualities. It is, moreover, easy to construct, is mechanically strong, and very little likely to receive injury. It has but one unfortunate characteristic. It is all but impossible to make use of a variable resistance in its circuit.

We have seen that a motor with a slow resistance winding in its secondary, may have a high efficiency, and run at a constant speed for all loads within its rated output, but its starting effort is small. Conversely, a motor may be made with a higher secondary resistance, and its starting torque, therefore, may be almost anything that is desired, but the speed regulation is likely to be poor, and the efficiency not so satisfactory. It is quite necessary in many classes of service to make use of a motor that is efficient, that will run at a constant speed, and that will have a high starting torque. It is practically impossible to secure all of these advantages without using some form of variable secondary resistance. To accomplish this, the secondary is given a winding similar to that used for the primary, and the resistance is inserted in the lines, so as to close the circuit. This resistance may be a part of the motor, or it may be entirely separate from the machine, connection being made through slip rings.

The secondary winding must evidently be made such as is suitable for a particular number of poles. Given secondary conductors are always in series, and each must carry the same current as the others. The E.M.F. induced in a circuit is the sum of the E.M.F.'s induced in conductors lying at various points on the rotor. An irregularity in flux that is localized on the rotor does not at once generate a corresponding localized current and the secondary reactions do not therefore smooth out the flux wave to any great extent. The magnetic reactions of the currents in a wound secondary are not therefore such as force a sine flux distribution. The starting current of a motor having a variable secondary resistance is much less for the same torque than that of a commercially practicable motor having a fixed secondary resistance.

The squirrel cage motors, as ordinarily put upon the market, have end rings made of special alloys, having considerable resistance, and their performance is a compromise which gives a fair efficiency and speed regulation, an exceedingly large starting current, and a good starting torque. There are no theoretical differences in the operation of the two classes of motors which involve a change in the treatment already given.

(*b*) *Effect of a Change in the Number of Poles.*

When a motor speed and frequency are both fixed, as is sometimes the case, the number of poles is arbitrarily determined. When either of these values is not specified, the number of poles may theoretically be any even number. Practically, it is found highly desirable to keep the number of poles as small as possible. If a change be made in the winding of a given motor frame, such as to increase the number of poles, it is obvious that the distance from pole to pole is reduced. But the magnetic leakage occurs along the air gap from one pole to the next, and a shortening of this path will, other things being equal, increase the leakage.

(*c*) *Effect of a Change in the Air Gap.*

A cardinal principle regarding the air gap is that it must be kept as short as possible, sufficient clearance being provided for mechanical safety. The air gaps of motors built at the present day are materially shorter than those of a few years since, owing to improved methods of manufacture. An increased air gap simply provides an increased area for leakage, and by demanding an increased magnetomotive force increases the actual leakage in two ways.

The effect upon the performance of a motor due to a wear of the bearings, and a consequent unequal air gap at the top and bottom of the machine, is of some interest. If the primary be wave wound, the E.M.F. of a single circuit is distributed around the primary ring, and may be quite unequal at different points. Where the reluctance of a magnetic circuit has been reduced by wear in the bearings, and a consequent decrease in the air gap, the flux will be greatly increased. Where the air gap has been increased, the flux is correspondingly lessened.

TABLE I.

RUNNING CONDITIONS OF TWO-PHASE VOLT MOTORS WITH SQUIRREL-CAGE ROTORS.

Horse-Power.	Speed in R. P. M.		Efficiency in Per Cent		Per Cent Power. Factor.		Max. Torque Terms of Full Load.
	Syn's	Load.	Half Load.	Full Load.	Half Load.	Full Load.	
1	1800	1690	77	80	72	88	2·6
3	1800	1690	75	80	72	88	2·7
5	1200	1130	79·5	82	76	89	2·6
7·5	1200	1130	80	82	81	91	2·75
10	1200	1130	80	82·5	81	91	3·2
15	1200	1130	83	84·5	82	90	2·8
20	1200	1130	84	84·5	80	91	2·7
30	900	845	85	85	81	90	2·8
40	900	850	86	86·5	78	90	
50	900	850	88	88	86	93	3·5

If a lap wound primary be used, each current circuit is localized, and since the primary flux is dependent upon the E.M.F. of a circuit, and that of all circuits is equal, the flux at a pole is independent of irregularities in the air gap.

There cannot therefore be unbalanced magnetic pulls on the rotor of a lap wound machine, while these might be serious in the case of one that is wave-wound.

(*d*) *Effect of a Change in the Number of Slots.*

When the number of poles is fixed, a change in the number of slots is a change in the quantity known as the "slots per phase per pole," and if the total number of conductors remains the same, this also implies a change in the number of conductors per slot. These changes may alter the

Table II.

STARTING CONDITIONS OF TWO-PHASE CONSTANT SPEED MOTORS WITH SQUIRREL-CAGE ROTORS.

Horse-Power.	E. M. F.	Starting Torque.		Line Current.		Per Cent. Power Factor.
		Lbs. at One Foot Radius.	Terms of Full Load.	Amperes.	Terms of Full Load.	
1	200	7·2	2·4	14	5	60
3	200	23	2·5	40	5	62
5	200	51	2·2	55	4·2	60
5	130	23	1·	23	1·9	60
	100	12.5	·55	14	1·1	60
7·5	200	87	2·5	90	4·7	62
7·5	130	37	1.05	28	1·9	62
7·5	100	21	·60	23	1·2	62
10	200	131	2·8	140	5·6	62
10	130	54	1·15	59	2·2	62
10	100	32·5	·70	35	1·4	62
15	200	168	2·4	174	4·7	60
15	130	70	1·	74	2·6	60
15	100	42	·6	44	1·2	60
20	200	211	2·3	230	4·6	60
20	130	89	·97	97·	1·9	60
20	100	50·5	·55	58	1·2	60
30	200	495	2·3	345	4·6	63
30	130	176	·95	145	2	63
30	100	96	·52	86	1·2	63
40	200	584	2·4	525	5·25	65
40	130	248	1·0	220	2·0	65
40	100	136	·55	132	1·2	65
50	200	792	2·6	672	6·0	65
50	130	335	1·1	280	2·20	65
50	100	182	·6	170	1·35	65

behavior of the motor in two ways. First, an increase in the number of slots per phase per pole means that less M.M.F. is added to a circuit by the currents lying in one slot, and that the change in magnetic distribution from zero to a maximum is less abrupt, and the wave of magnetism belonging to a single pole is made to approximate more closely to a sine curve. This is highly desirable. Second, an increase in the number of slots means of winding that is more distributed, while a decrease in the number of slots involves a condensation of the windings. The former decreases the self-induction, and the latter increases it. For the second reason therefore it is also desirable to use a large number of slots.

The expense of shop construction is considerably increased by an increased number of slots, so that an actual motor is in this respect a compromise between initial cost and advantages of operation.

Experimental Constants from Typical Motors.—To illustrate the actual behavior of commercial machines, there will be given some test records taken from typical motors. These figures are for the most part from machines that were constructed during the year 1900. The first table shows the running conditions of a line of two phase, 200 volt motors having squirrel cage secondaries. They are designed to have a considerable starting torque, and the short circuiting end rings are made of an alloy of copper and german silver. The speed regulation and efficiency are as good as can be obtained under the circumstances.

The starting torque, starting current, and power factors of the same motors, and the variations in these with changes in the impressed pressure, are shown in the second table. It is seen that a very high starting torque is obtained if the full pressure is immediately thrown on, but this is only done by drawing from five to six times the normal primary current. The starting torque given by half the normal pressure, and something more than normal full-load current, is a little over half of the full-load torque. In the practical operation of these motors it is intended that the starting shall be accomplished at a reduced pressure.

The amount of current that a motor consumes when running without load, and the power factor at which this current is drawn, are quite important factors in determining its value. An average giving test results of this sort has been made for each of several classes and sizes of motors.

Taking the test records of twenty-eight different motors, of a type similar to those for which data are given in Tables 1 and 2, the motors being 60-cycle machines, and having capacities ranging from ½ to 200 horse-power, an average shows that 37 per cent. of the normal full-load current is drawn from the line, with the motors running unloaded. At the same time 5·5 per cent. of the rated power output is the average power consumed. This corresponds to a no-load power factor of about 13 per cent.

Similar figures taken from a line of two-phase 25-cycle motors gave for eleven machines, ranging in size from 1 to 20 horse-power, 34 per cent. of the full-load current, and power amounting to 5·3 per cent. of the rated output as required for light running. From thirteen similar machines of larger size, ranging from 30 to 500 horse-power, the figures were 33 per cent. of the normal full-load current and 4·1 per cent. of the power of the rated output of the motors.

Of three-phase motors averages were taken of the results of tests on twenty machines of capacities from ¼ to 100 horse-power. The average drop in speed of these motors from synchronous speed to that at full load was 5·5 per cent. The quarter horse-power machine required 85 per cent. of its normal full-load current when running light, and under these conditions used 61·5 watts, or 33 per cent. of its power output. Eight of the machines of capacities, from 2 to 15 horse-power, required 28 per cent. of the full-load current and 5·56 per cent. of the power output, and eleven of the larger sized motors, of capacities from 20 to 100 horse-power, required 26 per cent. of the full-load current and 5 per cent. of the power output for no-load running.

Similar figures are given in detail below for ten high-resistance motors designed for such duty as is required by cranes, hoists, etc.

The motors from which the figures given in the following table were taken, are all three-phase machines. A wide range of performance is found between individual motors of the same general character.

Horse-Power.	Cycles.	Speed Drop per cent. Synchronous to Full Load.	Per Cent. of Full Load Current to Run Light.	Per Cent. Power Factor to Run Light.
		Per Cent.	Per Cent.	Per Cent.
5	25	5	54·5	11·6
10	25	2·7	54	10·4
20	25	6	66	12·3
40	25	7·5	36	6
3	30	22·6	57·5	11·3
5	30	4	53·4	12·7
10	30	4·5	47·5	9·2
5	60	9	55	10·5
10	60	17·8	34·5	8·9
20	60	6·5	65	8

The results of tests that have been given in the preceding pages will serve to indicate about the sort of performance to be expected from induction motors at the present day. The usual limits that are set by a good designer for the variable factors which he controls, will be given in the next section.

Design Constants from Typical Motors.—The design constants that are given in this section were computed from machines built in this country during the year 1900. The writer was particularly fortunate in being able to secure this data, which is of a nature not usually available. Partial dimensions were obtained for nineteen different machines. Not all of the desired dimensions could be had in every case, and some of the constants could not be computed for all the motors. A considerable amount of material was, however, obtained. The motors are numbered consecutively, and a given number indicates the same motor on each of the pages.

The first seven motors have wound secondaries, and the remaining twelve motors have short-circuited or squirrel-cage secondaries. The motors of each group are arranged in order, according to size. The size is rated upon the diameter of the primary bore, and not upon the power output. All the machines except Nos. 8 and 16 are three phase. Nos. 8 and 16 are wound for two phases.

Motors Nos. 10, 14, and 15 are what is known as variable pole motors. The primary winding of one of these machines is arranged so that while at full speed it is *Y* connected with two circuits per phase, and a given number of poles; it may be changed by proper switching devices to a delta-connected motor, having one circuit per phase, and twice the number of poles as before. Synchronous speed with the latter connection is then half of synchronous speed with the former connection. The E.M.F. produced per circuit is 318 volts at full speed with the *Y* connection, and 550 volts at half speed with the delta connection. Since the pressure in the

Motor Number.	Outside Diameter Primary.	Inside Diameter Primary.	Outside Diameter Secondary.	Inside Diameter Secondary.	Horse-Power.	Speed in R.P.M.	Number of Poles.	Cycles per Second.	Primary E.M.F.	Length of Laminations Parallel to Shaft.	Length Occupied by Ducts.
1	26	19·07	19	14	16	720	10	60	440		
2	26	19·07	19	14	20	600	12	60	440	10	·75
3	32	24·08	24	18	30	450	16	60	440	9	·75
4	32	24·09	24	18	30	450	16	60	440	9	·75
5	32	24·08	24	18	50	450	16	60	440	14	·15
6	40	32·09	32	26	75	450	16	60	440	10·5	1
7	40	32·09	32	26	150	600	8	40	550	16	2
8	17	12·06	12	8	8	1333	6	66	550	6·75	0
9	21	15·07	15		7	480	10	40	110	7·5	0
10	40	32·09	32	26	50	480	10	40	550	7·5	·75
11	40	32·09	32	26	75	250	12	25	220	10·5	1
12	42	32·09	32	24	75	500	6	25	440	10·5	1
13	42	32·09	32	24	75	500	6	25	440	10·5	1
14	50	40·1	40	35	100	400	12	40	550	10	·75
15	50	48·⅛	48	40	150	300	16	40	550	17	1·5
16	58	48·⅛	48	40	560	450	16	60	190	17	1·5
17	70	60·	59·86		700	400	18	60	2200	16	1·5
18	76	60·	59·86	46	1200	375	8	25	352	24	3
19	84	70·25	70	62	250	187	16	25	3000	12	1·5

former case is generated with half the number of conductors in series, and with the flux moving at twice the speed, as in the latter case, the air gap induction densities must also be in the ratio of 318 to 550. The various flux densities given in the tables for these machines are for full speed. These should be multiplied by 1.73 ($\sqrt{3}$), to give the corresponding densities at half speed. It should be noted that the densities as set down in the tables are quite low as compared with those for the other motors, except for Nos. 8 and 9, which are of quite small capacity.

Motor Number.	PRIMARY.												Connection of Secondary.
	Number of Slots.	Slots per Phase per Pole	Width of Slot.	Depth of Slot.	Thickness of Insulation.	Connection.	Circuits per Phase.	Number of Conductors.	Conductors in Series.	Size of Conductors.	Mean Width of Tooth.		
1	120	4	·28	1·25	·055	Y	1	1200	400	Twin No. 12	·236		Wound.
2	96	—	·28	1·25	·055	—	—	—	—	—	·386		
3	144	3	—	—	—	—	—	—	—	—	—		
4	144	3	·27	1·30	—	—	—	—	—	—	·284		
5	144	3	·27	1·30	—	—	—	—	—	—	·284		
6	144	3	·34	1·30	·05	△	1	864	288	Twin No. 9	·386		
7	144	6	·375	1·25	·068	△	1	576	192	·1 x 4 bar.	·355		
8	72	4	·28	1·25	·05	2ϕ	2	3456	864	No. 18 B. & S.	·304		Squirrel Cage.
9	90	3	·28	1·25	·049	△	2	1620	270	No. 12 B. & S.	·292		
10	120	4	·38	1·50	·05	Y	2	1920	320	No. 8 B. & S.	·500		
11	144	4	·36	1·60	·062	△	1	576	192	·1 x ·6 bar	·375		
12	108	6	·40	1·60	·06	△	1	864	288	4 Twin No. 16 B.W.G.	·580		
13	108	6	·40	1·60	·068	Y	1	648	216	·6 x ·075 bar.	·580		
14	144	4	·44	1·70	·05	Y	2	1728	288	3—No. 10 B. & S.	·470		
15	192	4	·42	1·70	·05	Y	2	1536	256	4 Twin No. 13	·397		
16	192	6	·40	1·75	·05	2ϕ	4	384	48	2—·7 x 15	·417		
17	216	4	·49	1·70	·10	Y	1	864	288	1/8 x ·6 bar	·410		
18	144	6	·60	1·70	·05	△	2	288	48	2—·65 x 2	·845		
19	192	4	·56	2·20	·10	Y	1	2688	896	3—No. 12 B.W.G.	·620		

In studying the motor constants here given, and in making comparisons between them, it should be noted that a constant for any individual machine is subject to what may be termed accidental variations. Even with the motors of large size, these constants vary greatly in some cases. Such variations are mainly due to the necessity of making a given design conform to the standards of the shop in which it is to be constructed. Thus, while a particular size of tooth and slot may be perfectly suited to one motor, and not so well adapted to one having a different capacity or speed,

SECONDARY.

Motor Number.	Number of Slots.	Slots per Phase per Pole.	Width of Slot.	Depth of Slot.	Thickness of Insulation.	Connection.	Circuits per Phase.	Conductors per Slot.	Number of Conductors.	Conductors in Series.	Size of Conductor.	Mean Width of Tooth.	Peripheral Speed in Feet per Minute.
1	—	—	·36	1·13	·08	Y	2	2	—	—	2—·1 x ·4	—	3390
2	72	2	·36	1·13	·08	Y	2	2	144	24	2—·1 x ·4	·42	2820
3	96	2	·36	1·13	.08	Y	2	2	192	32	2—·1 x ·4	·39	2830
4	96	2	.36	1·13	·06	Y	1	4	384	128	·1 x ·4	·39	2830
5	96	2	·36	1·13	·08	Y	2	2	192	32	2—·1 x ·4	·39	2830
6	192	4	.285	1·03	·055	Y	1	2	284	128	·175 x 35	·22	3770
7	108	—	·32	1·33	—	—	—	—	—	—	—	·574	5030
8	—	—	·55	·63	—	P	Squirrel Cage.		—	2	·5 x ·5	—	4190
9	47	1·57	·55	·48	—	P			47	2	·5 x ·35	·425	1881
10	99	3·3	·562	·47	—	P			99	2	—	·438	4020
12	99	2·75	·55	·58	—	P			99	2	—	·448	2790
12	99	5·5	·552	·47	—	P			99	2	—	·438	4200
13	99	5·5	·562	·47	—	P			99	2	—	·438	4200
14	133	3·7	·562	·47	—	P			133	2	—	·371	4190
15	186	3·88	·55	·63	—	P			186	2	·5 x ·5	·25	3760
16	186	5·8	·562	·94	—	P			186	2	2—·35 x ·5	·233	5660
17	210	3·9	·562	·94	—	P			210	2	—	·32	6280
18	210	8·77	·55	·90	—	P			210	2	—	·334	5880
19	255	5·3	·56	·47	—	P			255	2	—	·30	3430

commercial conditions may demand that both motors be built with the same tools and from similar stampings. The design constants in such a line of machines cannot be kept entirely uniform, and some of the motors turned out by the shop are likely to be considerably better than others of the same general type.

Motor Number.	Flux per Pole at No Load in Maxwells.	Flux Density per Square Inch.			
		Average Over Air Gap at No Load.	Primary.		
			Average in Core — Over Section Carrying all Flux.	Average in Teeth.	Maximum in Teeth — Assuming a Sine Wave.
1	495,000	—	—	—	—
2	—	—	—	—	—
3	—	—	—	—	—
4	—	—	—	—	—
5	—	—	—	—	—
6	1,200,000	20,100	26,500	40,500	63,700
7	3,360,000	19,100	49,400	41,700	65,500
8	446,000	11,000	30,400	21,100	33,200
9	477,000	13,460	20,500	26,900	42,300
10	1,168,000	11,920	27,100	22,200	34,900
11	2,142,000	27,100	33,800	56,100	88,400
12	2,890,000	18,170	50,500	32,400	51,000
13	2,764,000	17,380	45,000	30,900	48,700
14	1,298,000	13,400	24,800	27,600	43,400
15	1,460,000	10,000	16,100	21,300	34,400
16	3,090,000	21,200	34,700	44,500	70,000
17	3,425,000	22,300	39,700	53,500	84,100
18	13,790,000	28,000	57,100	48,000	75,500
19	3,620,000	25,000	41,000	51,600	81,400

The item in which there is the best agreement between the various machines is that of circular mils per ampere. This was figured on the assumption that the product of the full-load efficiency and the full-load power factor would be ·8 in all cases. This brings the values given in the tables a little too high for the small machines and a little too low for those of larger size, but the values are approximately correct as an average.

Considerable variation is found in the volts generated per foot of active conductor. This quantity depends upon the peripheral speed of the flux, and upon the air-gap density. The motor (No. 18) having the largest number of volts per foot of active conductor, and also having a very high induction density in all parts of the magnetic circuit, is not one for which the design here given can be called successful.

Motor Number.	Flux Density in Secondary.			Volts per Foot of Active Primary Conductor.	Approximate Circular Mils per Ampere in Primary Conductor.	Per Cent. of Primary Circumference Occupied by Mean Primary Teeth.	Per Cent. of Secondary Circumference Occupied Mean Secondary Teeth.y	Ratio of Section of Primary Core to Section of Secondary Core.
	Average in Core—over Section Carrying Greatest Flux.	Average in Teeth.	Maximum in Teeth—Assuming a Sine Wave.					
1	—	—	—	—	670	46	—	1·61
2	—	—	—	—	—	58	54	1·61
3	—	—	—	—	—	—	52	—
4	—	—	—	—	—	51	52	1·41
5	—	—	—	—	—	51	52	1·41
6	35,700	53,400	84,000	1·94	500	53	44	1·34
7	80,000	34,300	54,000	2·45	600	49	64	1·63
8	—	—	—	—	600	52	—	·95
9	—	35,600	56,000	·63	660	51	44	—
10	26.300	30,700	48,300	1·22	700	57	44	·99
11	52,200	68,600	107,600	1·45	720	51	45	·94
12	45,700	46,800	73,700	1·94	640	59	44	·90
13	59,500	44,800	70.600	1·86	780	59	44	1·32
14	38,500	37.800	59.400	1·44	640	52	40	1·60
15	15,400	36,000	56,600	·96	570	49	31	·96
16	36,200	81,000	127,000	3·07	780	51	29	1·04
17	—	70,000	110,000	3·63	560	46	36	—
18	60,500	83,400	131,000	4·18	640	63	38	1·05
19	54,300	80,000	125,000	2·20	790	52	35	1·32

Motor No. 11 was the one chosen for the detailed study of Part One of this thesis. That motor had the highest induction density in the primary teeth of any here given; it was therefore particularly suitable for such a study. The results given in the table are, in the case of this motor, practically those found by the more elaborate study of Part One. If the results of the simple computations used in the preparation of these tables were accurate for such a motor as No. 11, they are even better for motors in which the iron is not worked to such high densities.

The induction densities found in these machines is in all cases very moderate as compared with those found in other classes of machinery. This is necessarily so, since every part of the magnetic circuit carries an alternating flux, and since, as we have seen, the motor is peculiarly sensitive to magnetic leakage.

[*To be concluded.*]

RADIO-ACTIVE CHANGE.

Messrs. Rutherford and Soddy, in a recent paper published in the *Philosophical Magazine*, discuss the products of radio-active change and their specific material nature, the synchronism between the change and the radiation, the material nature of the radiations, the law of radio-active change to chemical change, and the energy of radio-active change and the internal energy of the chemical action. Radio-activity, according to our present knowledge, they say, must be regarded as the result of a process which lies wholly outside the sphere of known controllable forces and cannot be created, altered or destroyed. Like gravitation, it is proportional only to the quantity of matter involved. Assuming that an atom of radio-active matter cannot produce less than one and not more than 200 "rays" or projected particles, the authors deduce 10^8 gram cal. per gram as the least possible estimate of the energy of radio-active change in radium. As the reaction which sets free more energy for a given weight than any other chemical change known, namely, the union of hydrogen and oxygen, liberates only approximately 4,000 gram cal. per gram of water produced, the energy of radio-active change must be at least 20,000 times, and may be 1,000,000 times as great as the energy of any molecular change. Calculating the rate at which this store of energy is radiated, the authors deduce that in 1 gram of uranium and thorium less than a milligram would change in a million years. In the case of radium, however, this amount must be changing per gram per year. Therefore, the "life" of the radium cannot be more than a few thousand years, on this minimum estimate, and it appears certain that the radium present in a mineral has not been in existence as long as the mineral itself, but is being continuously produced by radio-active change.—*Electrical World.*

Graphics of Carbon Disulphide, With Formulas and Vapor Table.

By Thomas M. Gardner.

To consider the properties of this vapor from the graphical standpoint and thus be able to see more clearly its value as a working fluid for heat engines, it was necessary to calculate the entropy values for a series of different temperatures and pressures, as there was no suitable table at hand. These several quantities in tabular form, with their equations, are given at the end of this article. Plate I consists of curves of the properties so determined.

The second plate is a temperature-entropy diagram with the constant-volume lines of McFarlane Gray, which show the entropy in a given volume at any temperature and pressure and the heat units contained. If a given volume of vapor of given state and pressure with corresponding temperature be taken, the total entropy will be the specific entropy of the liquid, to which is added the specific entropy of the vapor times its quality, both being multiplied by the weight of the working fluid. If now the pressure and temperature is diminished, v being constant, the entropies and the weight of the vapor are changed so that the retained energy is less than the original amount; we have

$$dE = f(t, \Phi, m).$$

This process occurs during the exhaust of the steam-engine.

Two different methods of constructing this chart may be followed: one a graphical method as devised by Capt. Sankey, and the other by comparison of the constant volume with the specific volume corresponding to that temperature minus the volume of 1 pound of its liquid. Since the increase in the volume is proportional to the latent heat r, and

$$r / T = \Phi v,$$

Φv is proportional to the increase in volume, the temperature during the operation being constant, we thus can tell the amount of heat weight present in the retaining vessel under the stated conditions, and so are able to lay out a curve.

Hyperbolic Expansion.—The constant-area curves of Plate III are drawn in the following manner: Different volumes of 1 pound of working fluid, at a common pressure, but with varying initial qualities, are assumed. Then, according to the formula,

$$pv = c,$$

the different expansion curves were drawn with the saturation curve as a reference line. It is seen that the amount of moisture during such an increase of volume decreases.

$$pv = p'v', \quad \frac{pv}{p'} = \frac{pbs}{p'}$$

Now

$$x = \frac{v'}{s'} = \frac{pbs}{p's'}$$

$$\varphi = \varphi_1 + x\frac{r}{T}$$

Substituting, we have

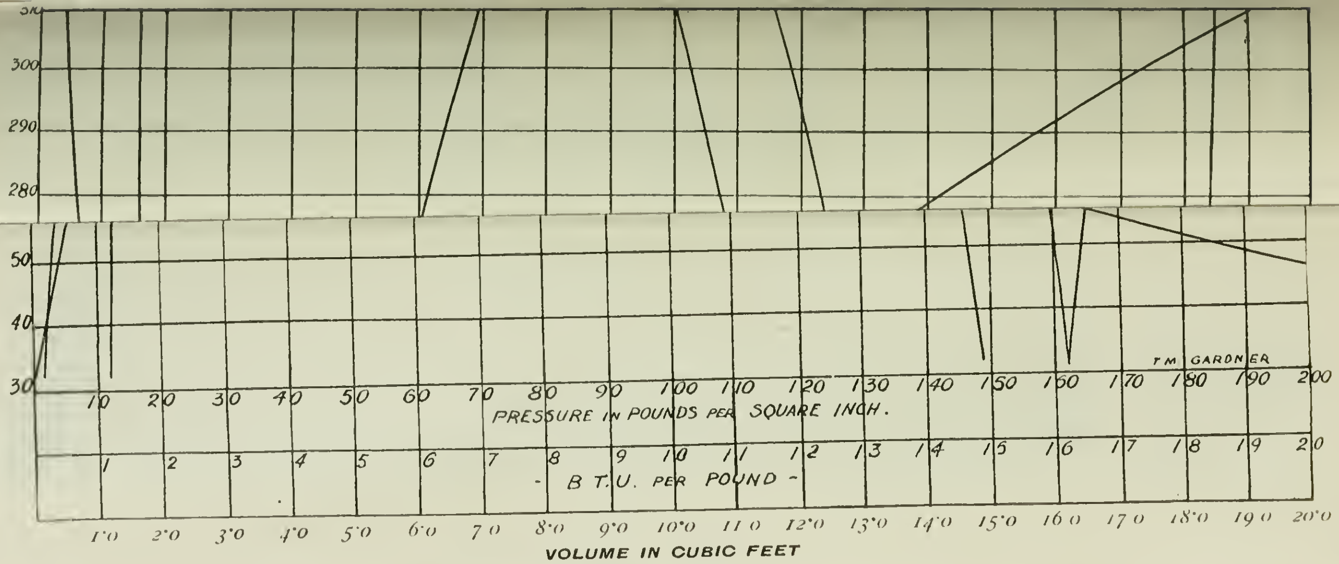
$$\varphi = \varphi_1 + \frac{pbs}{p's'}\varphi_v$$

$$\varphi = \varphi_1 + \frac{c\,\varphi_v}{p's'}$$

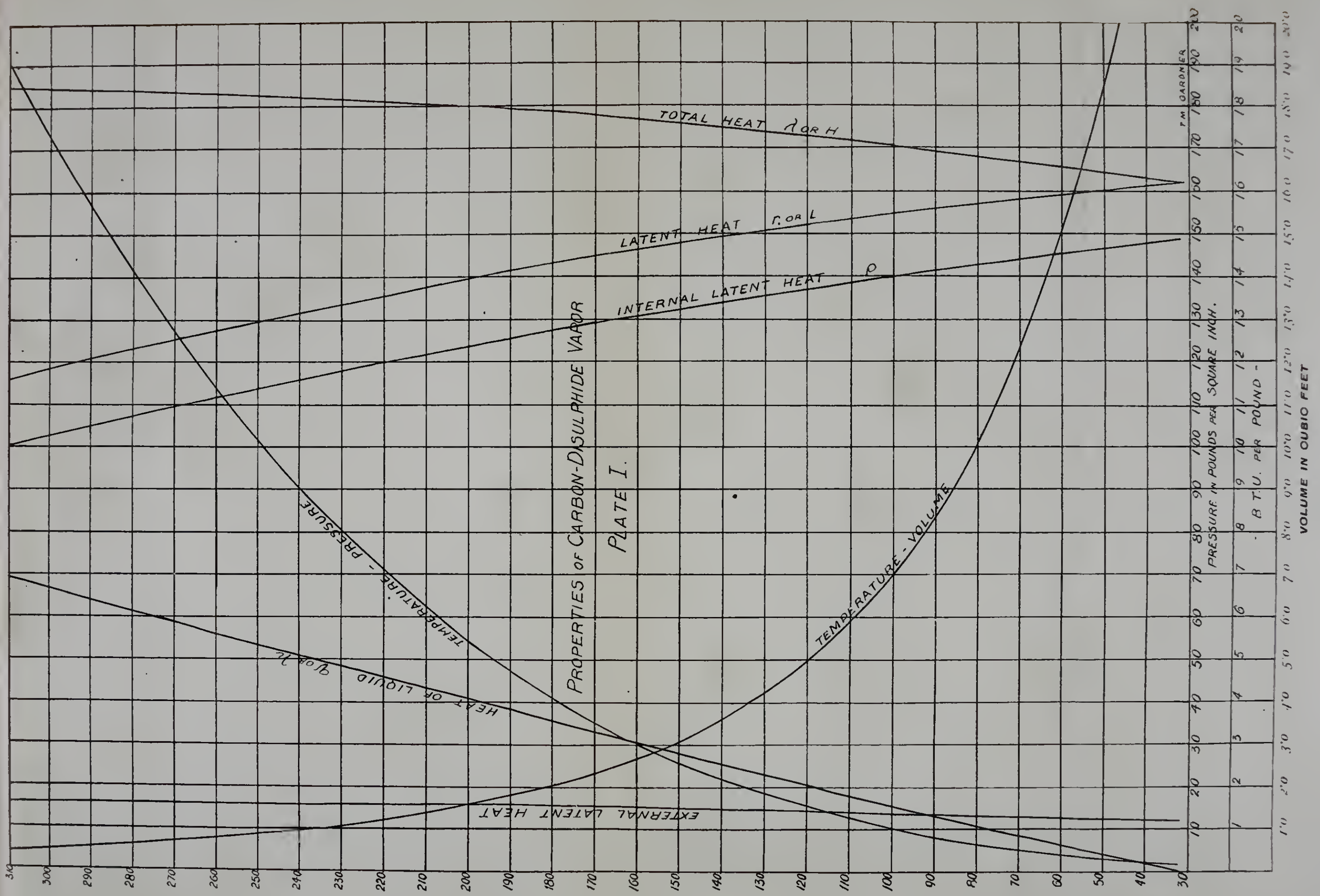
The total entropy of the volume considered is equal to the entropy of the liquid plus a quantity which is constant multiplied by the entropy of the vapor divided by the product of the absolute pressure times the specific volume; since for ordinary pressures the volume of the liquid may be neglected.

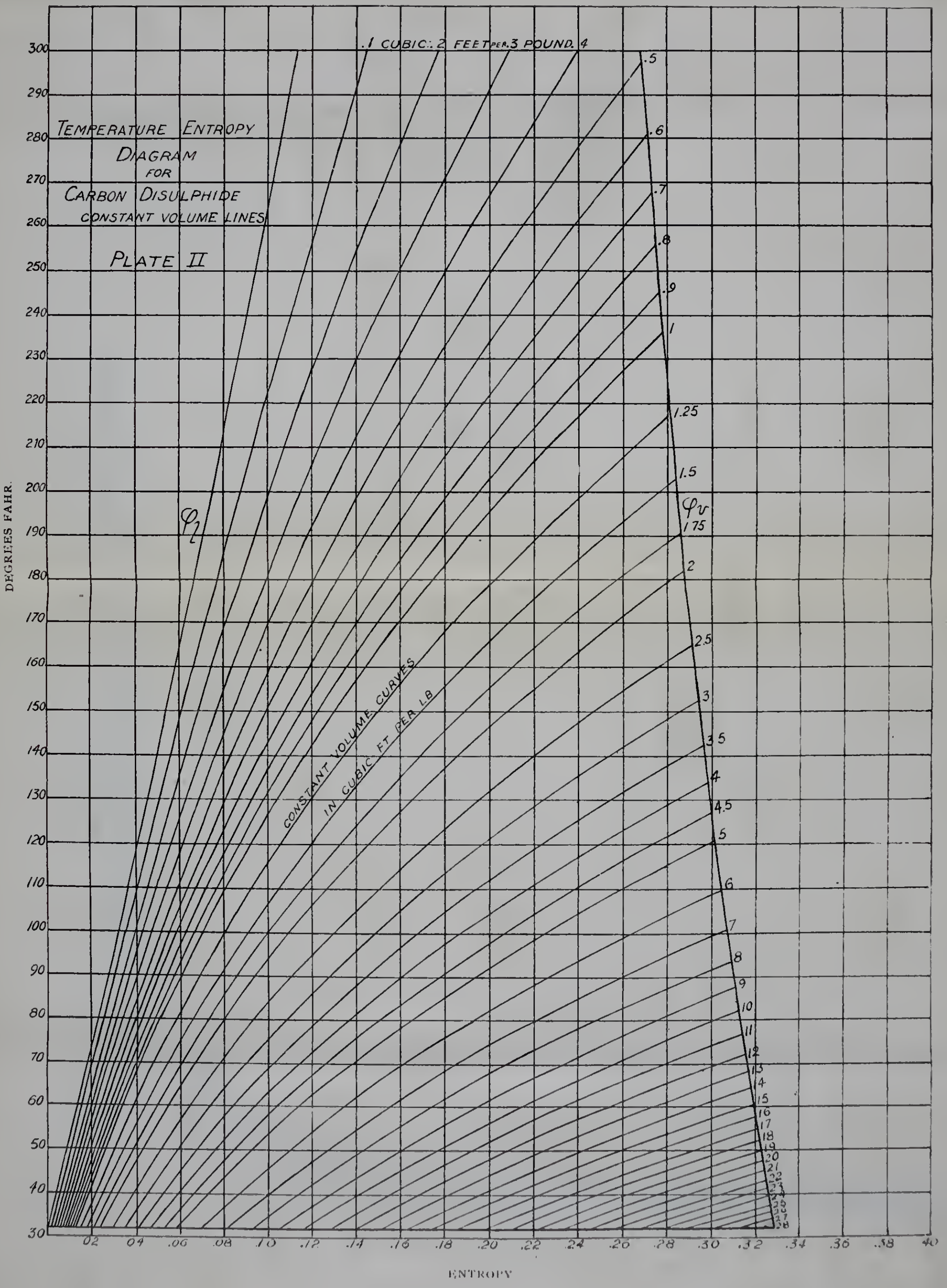
When the expansion of superheated vapor is considered according to $pv = c$, T being constant, all heat added is represented by external work, and the intrinsic energy is constant, so the entropy will be constant.

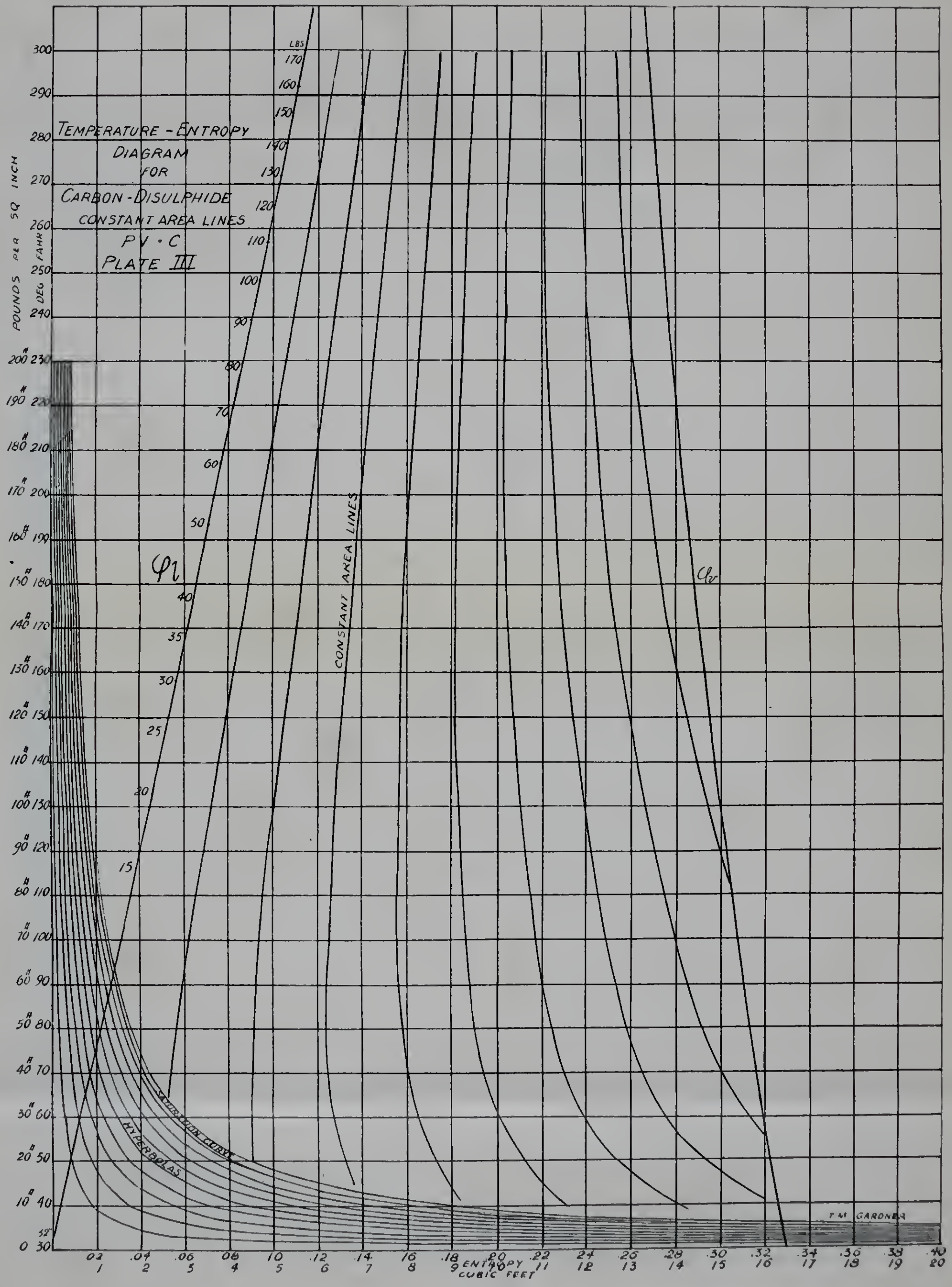
Constant Quality Curves.—Since the distance between the two entropy curves is proportional to r/T and represents the heat energy due to the increase in volume while the pound of liquid is evaporating till it is dry and saturated at that pressure, the quality is easily transferred from the

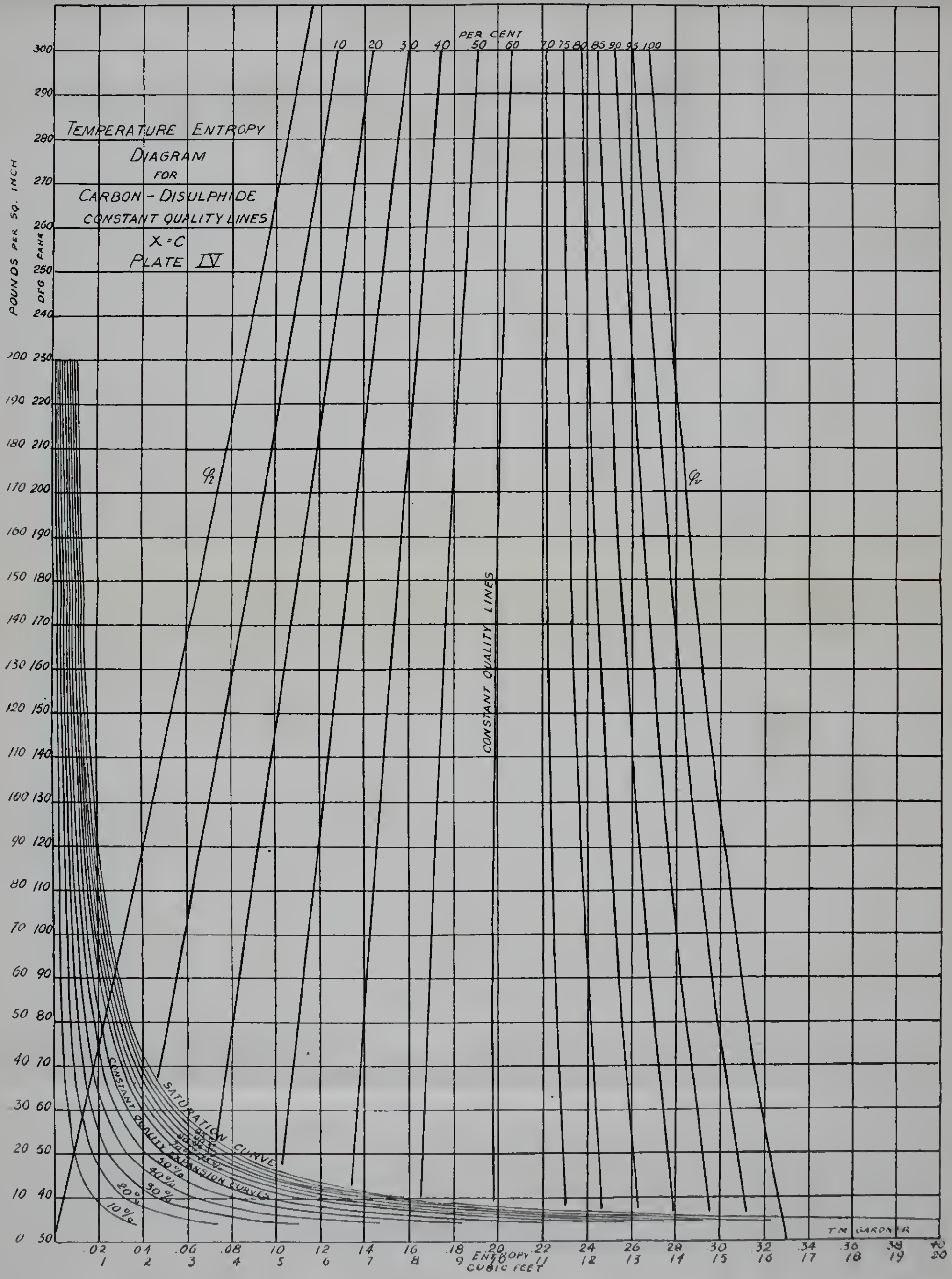

300
290
280
50
40
30
T M GARDNER
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
PRESSURE IN POUNDS PER SQUARE INCH.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
- B T. U. PER POUND -
1·0
2·0
3·0
4·0
5·0
6·0
7·0
8·0
9·0
10·0
11·0
12·0
13·0
14·0
15·0
16·0
17·0
18·0
19·0
20·0
VOLUME IN CUBIC FEET

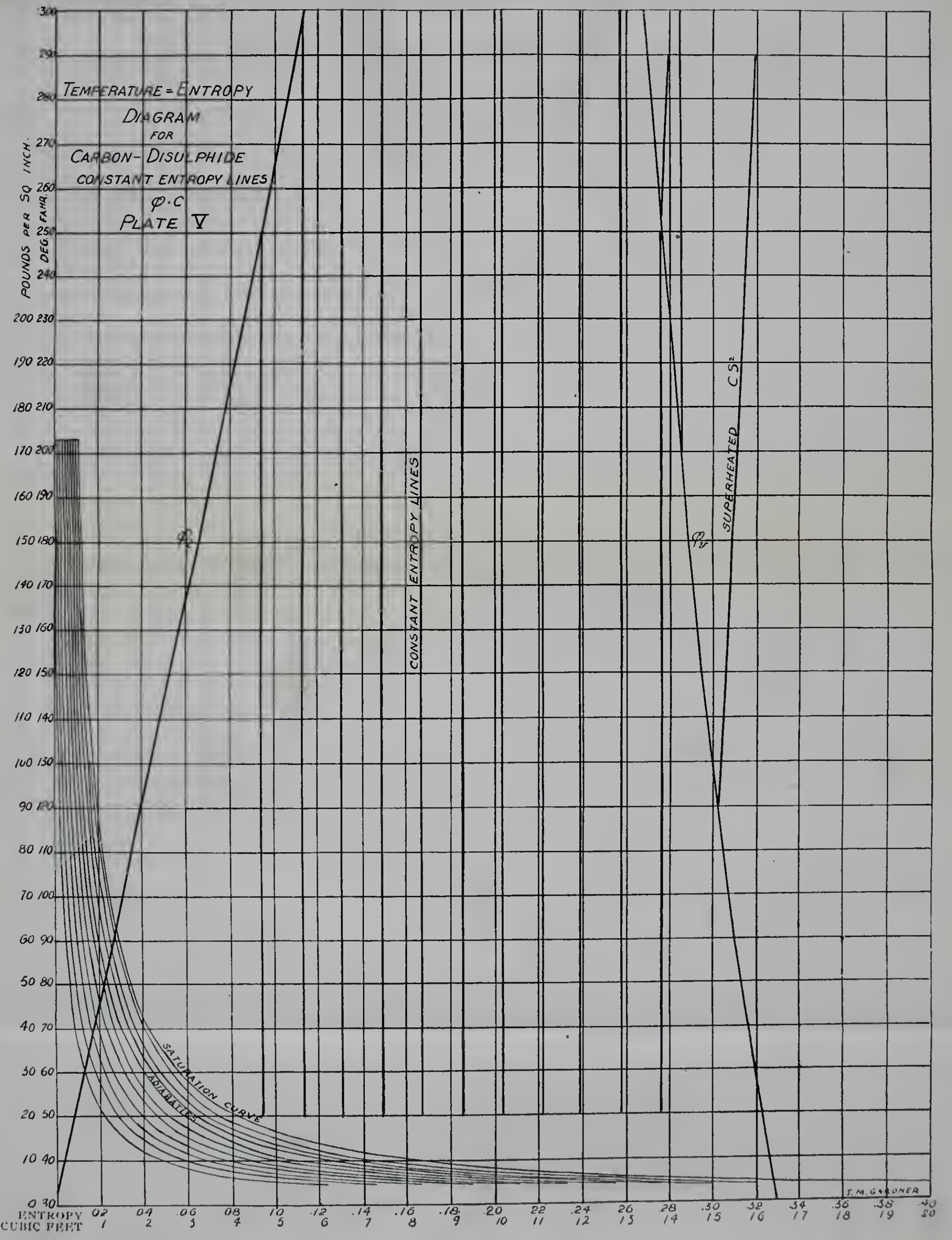
Jour. Frank. Inst., Vol. CLVI, October, 1903. (Gardner.)

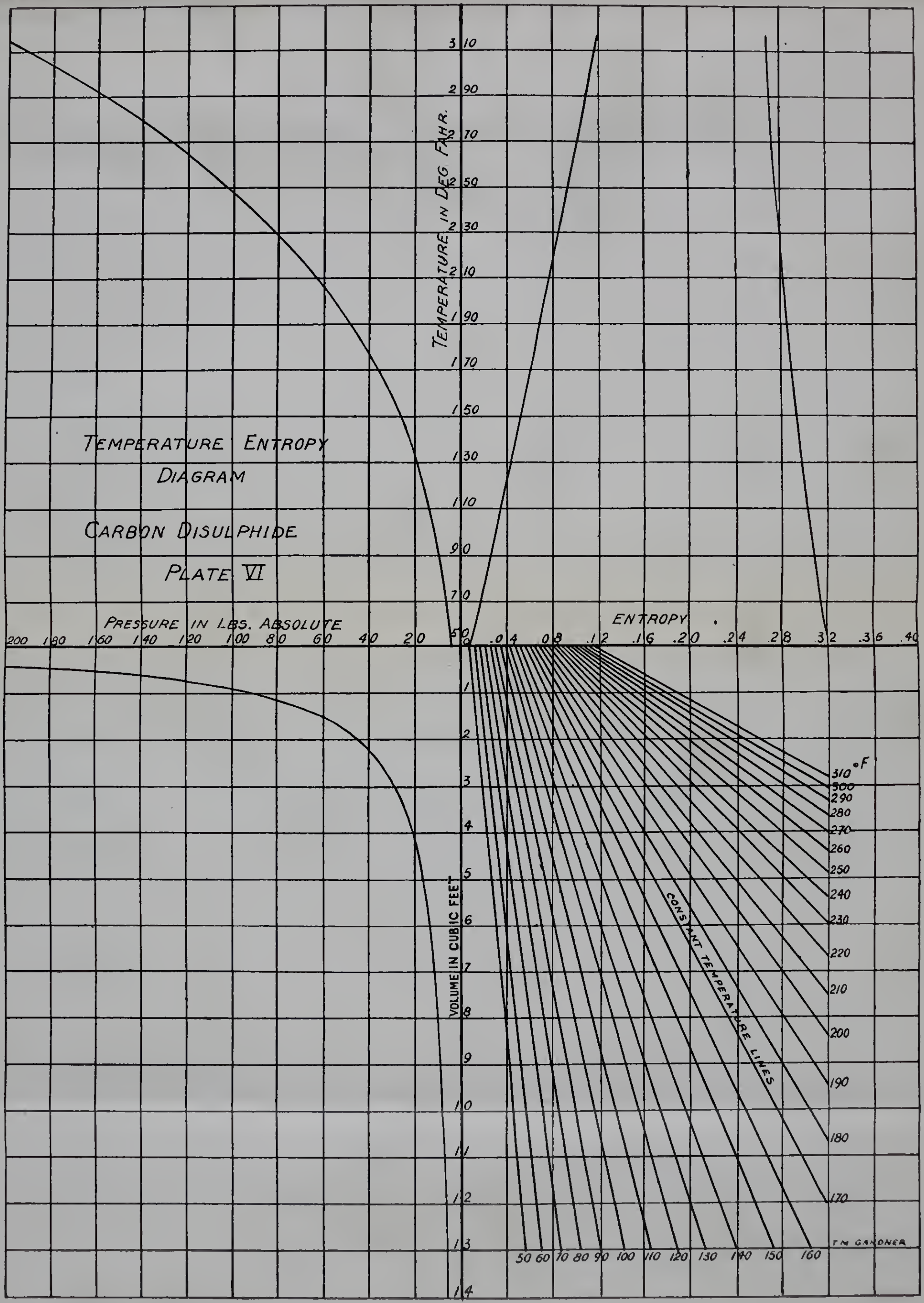



TEMPERATURE ENTROPY
DIAGRAM
FOR
CARBON DISULPHIDE
CONSTANT VOLUME LINES
PLATE II
.1 CUBIC .2 FEET PER .3 POUND .4
.5
.6
.7
.8
.9
1
1.25
1.5
φv
1.75
2
2.5
3
3.5
4
4.5
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
φl
CONSTANT VOLUME CURVES
IN CUBIC FT PER LB
DEGREES FAHR.
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
.24
.26
.28
.30
.32
.34
.36
.38
.40
ENTROPY


TEMPERATURE - ENTROPY
DIAGRAM
FOR
CARBON - DISULPHIDE
CONSTANT AREA LINES
PV · C
PLATE III
POUNDS PER SQ INCH
DEG FAHR
300
290
280
270
260
250
240
200" 230
190" 220
180" 210
170" 200
160" 190
150" 180
140" 170
130" 160
120" 150
110" 140
100" 130
90" 120
80" 110
70" 100
60" 90
50" 80
40" 70
30" 60
20" 50
10" 40
32°
0 30
LBS
170
160
150
140
130
120
110
100
90
80
70
60
50
40
35
30
25
20
15
φl
φv
CONSTANT AREA LINES
SATURATION CURVE
HYPERBOLAS
.02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .22 .24 .26 .28 .30 .32 .34 .36 .38 .40
ENTROPY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
CUBIC FEET
T M GARDNER


TEMPERATURE ENTROPY
DIAGRAM
FOR
CARBON-DISULPHIDE
CONSTANT QUALITY LINES
X = C
PLATE IV
POUNDS PER SQ. INCH
DEG FAHR
PER CENT
10 20 30 40 50 60 70 75 80 85 90 95 100
CONSTANT QUALITY LINES
SATURATION CURVE
CONSTANT QUALITY EXPANSION CURVES
10% 20% 30% 40% 50%
ENTROPY
CUBIC FEET
T. M. GARDNER

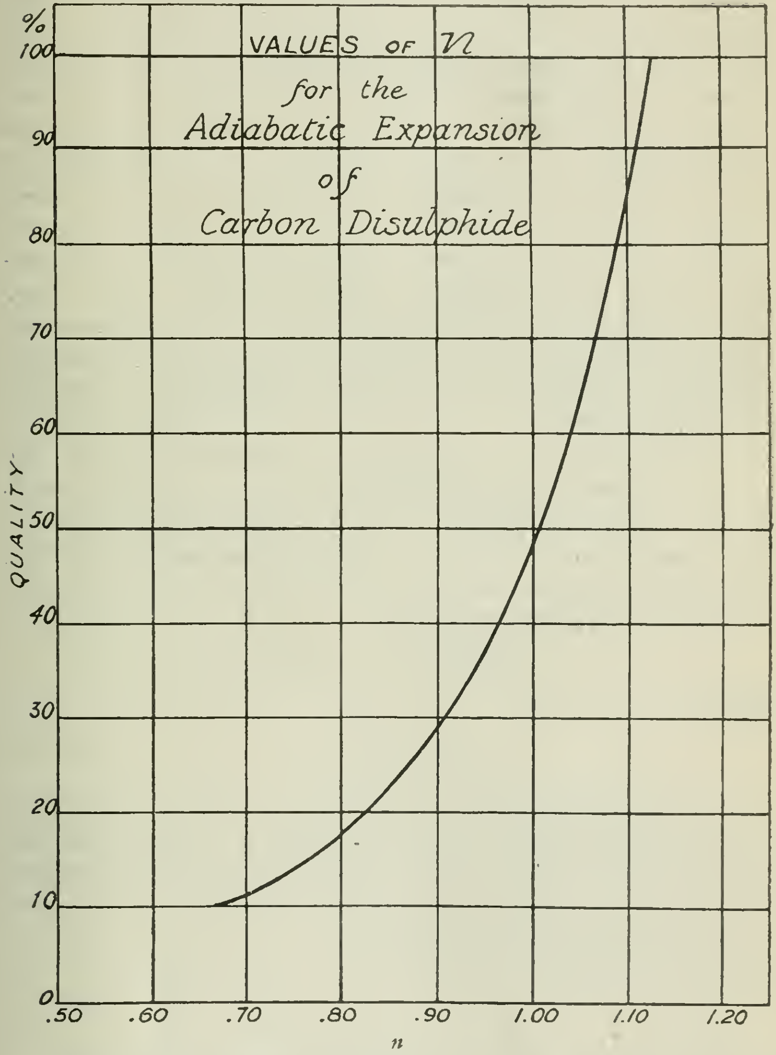

TEMPERATURE = ENTROPY
DIAGRAM
FOR
CARBON-DISULPHIDE
CONSTANT ENTROPY LINES
φ·C
PLATE V
POUNDS PER SQ INCH.
DEG. FAHR.
300
290
280
270
260
250
240
200 230
190 220
180 210
170 200
160 190
150 180
140 170
130 160
120 150
110 140
100 130
90 120
80 110
70 100
60 90
50 80
40 70
30 60
20 50
10 40
0 30
ENTROPY .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .22 .24 .26 .28 .30 .32 .34 .36 .38 .40
CUBIC FEET 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
φ_L
CONSTANT ENTROPY LINES
φ_V
SUPERHEATED CS²
SATURATION CURVE
ADIABATICS
T. M. GARDNER


TEMPERATURE ENTROPY
DIAGRAM
CARBON DISULPHIDE
PLATE VI
TEMPERATURE IN DEG. FAHR.
310
290
270
250
230
210
190
170
150
130
110
90
70
50
PRESSURE IN LBS. ABSOLUTE
200
180
160
140
120
100
80
60
40
20
ENTROPY
.04
.08
.12
.16
.20
.24
.28
.32
.36
.40
VOLUME IN CUBIC FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
CONSTANT TEMPERATURE LINES
310 °F
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
T. M. GARDNER

PROPERTIES OF SATURATED VAPOR OF CARBON DISULPHIDE.

Deg. Fah.	Absolute Scale.	Lbs. Per Sq. In.	Lbs. Sq Ft	Heat Liquid. q	Total Heat. λ	Heat of Vaporization. r	Internal Latent Heat. ρ	External Latent Heat. Apu	Entropy of Liquid. $\phi_1 = \int_c \frac{dt}{T}$	Difference per Deg.	Entropy of Vapor. $\phi_v = \frac{r}{\tau}$	Dif. per Deg.	Total Entropy. φ	Dif. per Deg.	$\frac{dp}{dt}$	° from $\tan\frac{dp}{dt}$	Specific Vol. v	Vol. of Liquid. Co. Ft.	Wt. of 1 Co. Ft. Vapor $\frac{1}{v}$	Deg. Fah.
32	492·66	2·46870	355·492	·000018	161·9976	161·9976	149·0573	12·9403	·000000	. . . . .	·328822	. . . .	·328822	. . . .	·062733	3° 35′	28.33259	·012570	·035295	32
35	495·66	2·66280	393·448	·706078	152·4336	161·7276	148·7110	13·0166	.001430	.000477	·326287	·000865	·327717	·000368	·065765	3° 49′	26·42267	·012596	·037845	35
40	500·66	3·01431	431·063	1·8847	163·1513	161·2666	148·1927	13·0739	·003801	·000474	·322108	·000335	·325909	·000361	·073324	4° 14′	23.44588	·012640	·041514	40
45	505·66	3·42490	493·311	3·0656	163·8576	160·7919	147·5402	13·2518	·006159	·000471	·317984	·000824	·324143	·000353	·081704	4° 40′	21.03197	·012624	·047529	45
50	510·66	3·83180	551·780	4·2489	164·5524	160·3035	146·9643	13·3392	·008500	·000468	·313914	·000816	·322414	·000345	·089967	5° 8′	18·82083	·012727	·052133	50
55	515·66	4·30370	619·737	5·4343	165·2357	159·8013	146·3165	13·4849	·010829	·000465	.309837	.000803	·310726	·000337	.098905	5° 31′	16·94157	·012771	·059127	55
60	520·66	4·82190	691·357	6·6121	165·9076	159·2854	145·6309	13·6545	·013141	·000463	·305930	·000793	·319074	·000330	·108038	6° 10′	15·31182	·012815	·065299	60
65	525·66	5·38970	776·121	7·8121	166·5679	158·7558	145·0475	13·7083	·015446	·000460	·302012	·000783	·317458	·000323	·118745	6° 46′	13·71437	·012859	·072703	65
70	530·66	6·01050	865.516	9·0044	167·2169	158·2125	144·3953	13·8172	·017735	·000458	·298142	·000774	·315877	·000316	·129696	7° 23′	12·43293	·012902	·080431	70
75	535·66	6·68300	963.667	10·1991	167·8545	157·6554	143·7321	13·9233	·020012	·000455	·294320	·000764	·314330	·000309	.141375	8° 3′	11·23478	·012946	·089009	75
80	540·65	7·42550	1069·270	11·3959	168.4805	157·0846	143·0342	14·0604	·022276	·000452	·290542	·000756	·312818	·000302	.153446	8° 44′	10·23662	·012990	·097625	80
85	545·66	8·22900	1184·972	12·5951	169·0951	156·5000	142·3707	14·1293	·024528	·000450	·286809	·000747	·311337	·000296	·167039	9° 29′	9·28971	·013013	·107645	85
90	550·66	9·09680	1309·965	13·7963	169·6982	155·9217	141·6729	14·2288	·026769	·000448	·283118	·000738	·309887	·000290	·181002	10° 16′	8·46384	.013077	·118151	90
95	555·66	10·0385	1445·541	15·0002	170·2900	155·2898	140·9638	14·3260	·028998	·000445	·279469	·000729	·308467	·000284	·195828	11° 6′	7·74126	·013121	·129173	95
100	560·66	11·0566	1591·147	16·2061	170·8701	154·6640	140·2429	14·4211	·031214	·000443	·275865	·000725	·307080	·000277	·211505	11° 57′	7·05999	·013164	·141643	100
105	565·66	12·1552	1750·340	17·4145	171.4392	154·0246	139·5112	14·5132	·033421	·000441	·272292	0.0714	·305713	·000272	·228052	12° 57′	6.46409	·013208	·154701	105
110	570·66	13·3386	1920·758	18·6250	171·9964	153·3714	138.7684	14·6030	·035619	·000439	·268762	·000706	·304381	.000266	·245491	13° 48′	5·92817	·013252	·168686	110
115	675·66	14·5744	2098·717	19·8379	172·5423	152.7014	138·0142	14·6902	·037802	·000437	·265268	·000698	·303070	·000262	·263177	14° 41′	5·44901	·013296	·183184	115
120	580·66	15·9786	2300·922	21·0529	173·0766	152·0233	137·2487	14·7750	·039977	·000436	·261811	·000691	·301788	·000256	·281133	15° 49′	5·02267	·013339	·199097	120
125	585·66	17·6675	2544·113	22·4703	173·5996	151·3293	136·4722	14·8571	·042141	·000433	·258391	·000685	·300532	·000251	·308145	17° 5′	4·55675	.013383	·219455	125
130	590·66	19·0142	2738·044	23·4899	174·1112	150·6213	135·6848	14·9366	·044295	·000431	·255005	·000677	·299300	·000246	·324619	17° 59′	4·25757	·013127	.234873	130
135	595·66	20·6924	2979·706	24·7118	174·6112	149·8994	134·8861	15·0133	·046440	·000429	·251653	·000670	·298093	·000241	·346864	19° 8′	3·93343	·013470	·254231	135
140	600·66	22·4848	3245·197	25·9350	175·0988	149·1638	134·0766	15·0873	·048576	·000427	·248335	·000664	·296909	·000237	·370086	20° 17′	3·63885	·013514	·274812	140
145	605·66	24·3950	3512·884	27·1625	175.5770	148·4145	133·2561	15·1584	·050700	·000425	·245046	·000657	·295746	·000233	·394362	21° 31′	3·37070	·013558	·296674	145
150	610·66	26·4298	3805·884	28·3913	176·0428	147·6515	132·4747	15·2268	·052816	·000423	·241796	·000650	·294612	.000227	·419685	22° 46′	3·12627	·013602	·319870	150
155	615·66	28·5937	4117·486	29·6223	176·4970	146·8747	131·5824	15·2923	·054921	·000422	·238565	·000646	·283489	·000224	·446071	24° 2′	2·90312	·013645	·344453	155
160	620·66	30·9636	4448·499	30·8556	176.9398	146·0842	130·7294	15·3548	·057023	·000420	·235372	·000638	·292394	·000218	·473539	25° 20′	2·69910	·013689	·370490	160
163	625·66	33·2694	4790·791	32·0912	177·3712	145·2800	129·8656	15·4144	·059112	·000418	.232202	·000633	·291315	·000216	·501171	26° 37′	2·51695	·013733	·39731	165
170	630·66	35·8340	5160.100	33·3320	177·7941	144·4621	128·9915	15·4706	·061194	·000416	·229066	·000627	·290260	·000213	·522336	27° 58′	2·34597	·013776	·42026	170
175	635·66	38·6503	5565·650	34·5692	178·1996	143·6304	128·1062	15·5241	·063267	·000415	·225955	·000622	·289222	·000207	·562346	29° 22′	2·18393	·013820	·45789	175
180	640·66	41·5399	5981·748	35·8116	178·5966	142·7850	127·2107	15·5743	·065331	·000413	·222872	·000617	·288203	·000204	·594417	30° 44′	2·03950	.013864	·49032	180
185	645·66	44·4422	6399·672	37.0529	178·9787	141·9258	126·3176	15·6082	·067391	·000412	·219815	·000112	·287206	·000200	·625091	32° 1′	1·91381	·013907	·52251	185
190	650·66	47·8194	6885·992	38·2997	179·3525	141·0528	125·3869	15·6659	·069437	·000409	·216784	·000605	·286211	·000197	·661722	33° 30′	1·78593	·013951	·56056	190
195	655·66	51·1562	7366·588	39·5487	179·7151	140·1664	124·4593	15·7071	·071478	·000408	·213779	·000601	·285257	·000192	.696251	34° 51′	1·67185	·013995	·59778	195
200	660·66	54·7921	7890·056	40·8041	180.0701	139·2660	123·5216	15.7444	·073512	·000407	·210798	·000596	·284310	·000189	·733582	36° 16′	1·56656	·014039	·63822	200
205	665·66	58·5537	8431·729	42·0536	180·4055	138·3519	122·5728	15·7791	·075538	·000405	·207842	·000591	·283389	·000186	·771268	37° 39′	1·47003	·014082	·68013	205
210	670·66	62·7951	9042·500	43·3141	180·7381	137·4241	121·6141	15.8100	·077556	·000404	·204909	·000587	·282465	·000183	·813869	39° 9′	1·39437	·014126	·72765	210
215	675·66	66·6581	9598·762	44·5726	181·0552	136·8426	120·6450	15·8376	·079566	·000402	·201999	·000580	·281567	·000178	.850182	40° 22′	1·29784	·014170	·77050	215
223	780·66	71·0202	10225.485	45·8330	181·3604	135·5274	119·6657	15·8617	·081572	·000401	·199112	·000577	·280684	·000173	·891392	41° 43′	1·22104	·0142133	·81597	220
225	685·66	75·6890	10899.211	47·0959	181·6553	134·5584	118·5840	15·8700	.083568	·000399	·196246	·000573	.279814	·000172	·935233	43° 5′	1·14708	·0142570	·87177	225
230	690·66	80·3510	11570·539	48·3611	181·9368	133·5757	117·6766	15·8991	·085560	·000398	·193403	·000569	·278963	·000170	·977401	44° 21′	1·07338	·0143007	·93164	230
235	695·66	85·3487	12290·215	49·6286	182·2038	132·5752	116·6528	15··995	·087545	·000397	·190575	·000565	·278120	·000168	1·02217	45° 38′	1·02105	·0143444	·97881	235
240	700·66	92.5741	13042·667	50·8983	182·4673	131·5690	115·6461	15·9229	·089521	·000395	·187777	·000559	·277298	·000164	1.06814	46° 53′	·964198	·0143881	1.03713	240
245	705·66	96·0322	13828·634	52·1704	182·7155	130·5451	114·6159	15·9129	·091493	·000394	·181997	·000556	·276491	·000161	1·115264	48° 7′	·910610	·0144318	1·09817	245
250	710·66	101·7287	14648·946	53·4447	182·9522	129·5075	113·5761	15·9314	·093158	·000393	·182235	·000552	·275693	·000159	1·163647	49° 20′	·860589	·0144756	1·16199	250
255	715·66	107·6703	15540·261	54·7213	183·1774	128·4561	112·5254	15·9307	·095417	·000392	·179491	·000548	·274908	·000157	1·20479	50° 30′	·813902	·0145193	1·22865	255
260	720·66	113·8625	16396·200	56·0001	183·3911	127·3910	111·4650	15·9260	·097369	·000390	·176770	·000542	·274139	·000154	1·26383	51° 39′	·770243	·0145630	1·29829	260
265	725·66	120·3107	17234·786	57·2812	183·5934	126·3122	110·3252	15·9170	·099315	·000389	·174067	·000441	·273382	·000151	1·315692	52° 46′	·729490	·0146067	1·37080	265
270	730·66	127·0212	18291·055	58·5647	183·7845	125·2196	109·3152	15·9044	·101256	·000388	·171378	·000538	·272634	·000149	1·368728	53° 51′	·691136	·0146504	1·44689	270
275	735·66	133·9993	19295·942	59.8504	183·9638	124·1134	108·2255	15·8880	·103192	·000387	·168710	·000533	·271902	·000146	1·422912	54° 54′	·665284	·0146941	1·52000	275
280	740·66	141·2527	20340·384	61·1383	184·1317	122·9934	107·1260	15·8674	·105120	·000386	.166059	·000530	·271179	·000144	1·478267	55° 55′	·621652	·0147378	1·60863	280
285	745·66	148·7840	21424·906	62·4286	184·2882	121·8596	106·0136	15·8430	·107043	·000385	·163425	·000526	·270468	.000142	1·534753	56° 55′	·590086	·0147815	1·69468	285
290	750·66	156·6022	22550·731	63·7213	184·4324	120·7112	104·8968	15·8144	·108962	·000384	·160807	·000523	·269769	·000139	1·592395	57° 52′	·560410	·0148252	1·78438	290
295	755·66	164·7103	23717·278	65·0160	184·5668	119·5509	103·7690	15·7819	·110874	.000382	·158207	·000520	·269081	·000137	1·651151	58° 48′	·532544	·0148689	1.87779	295
300	760·66	172·8305	24887·598	66·3130	184·6890	118·3760	102·6308	15·7452	·112781	·000381	·155623	·000516	·268404	·000135	1·708222	59° 39′	·507004	·0149126	1·972237	300
305	765·65	181·8221	26182·384	67·6123	184·7996	117·1873	101·4829	15·7044	·114683	·000380	·153054	·000513	·267739	·000133	1·772028	60° 39′	·481606	·0149563	2.07630	305
310	770.66	190·8359	27480·323	68·9140	184·8989	115·9849	100·3220	15·6629	·116580	·000371	·150501	·000510	·267081	·000131	1·834106	61° 14′	·458333	·0150000	2·18182	310
315	775.66	200·1658	28423·747	70·2179	184·9866	114·7689	99·1587	15.6700	·118467	000·377	·147963	·000507	·266430	·000130	1·897304	62° 12′	·436384	·0150435	2·29156	315

temperature entropy to the pressure-volume diagram. We have a series of curves with exponents the same. The expression is $pv^{1.0568} = c$.



Adiabatic Expansion.—In this theta-phi diagram constant entropy lines are drawn, from which we may obtain the quality of the vapor, by taking the distance from the entropy of the liquid curve to the adiabatic and dividing by the distance Φ_v.

In Plate V a pressure of 101 pounds absolute is taken and divided into ten equal parts, giving qualities ranging from 10 to 100 per cent. Letting the different mixtures of the fluid and its vapor expand adiabatically, we see that the amount of contained moisture increases for all qualities above 70 per cent. and decreases for all values of the dryness fraction below 60 per cent. Beginning at a temperature of 250° F. and expanding down to 50° adiabatically, if the same quality is desired at the end as at the beginning, a value of 64·5 per cent. must be taken. Starting with 100° of superheat above 250° saturation and expanding in the same manner, the final temperature will be 198° when the superheat has disappeared. It may further be said that when we compress saturated vapor of carbon disulphide it becomes an imperfect gas.

The following table will show the values of n when the fluid expanding adiabatically has the initial quality modification. These, if plotted on cross-section paper, give a logarithmic curve, which becomes plain when drawn on logarithmic cross-section sheet, when it gives a straight line. Solving, we have the equation

$$xn^{-6 \cdot 36} = c, \text{ or } x \div n^{6 \cdot 36} = c;$$

whence

$$n = \left(\frac{x}{c}\right)^{\frac{1}{6 \cdot 36}}$$

Plate VI.—This Boulvin $\theta\ \Phi$ chart is for the purpose of quickly transferring the indicator diagram, representing the pressure-volume history of 1 pound of CS_2 in the engine cylinder, to the temperature-entropy quadrant and thus give us the desired heat representation.

Equations of Carbon Disulphide.

$$\log p = A - \frac{B}{\tau} - \frac{C}{\tau^2}$$

$$\tau = 1 \div \left[\sqrt{\left(\frac{A - \log p}{C} + \frac{B^2}{4C^2}\right)} - \frac{B}{2C} \right]$$

$$A = 7 \cdot 4263 \quad \log B = 3 \cdot 3274293 \quad \log C = 5 \cdot 1344146$$

$$\frac{dp}{dt} = 2·30258\, p \left(\frac{B}{\tau^2} + \frac{2C}{\tau^3}\right) \quad \left[\frac{dp}{dt} = \tfrac{1}{144} \text{ of this value in table.}\right]$$

$$q = -\,7·480711 + 0·232314\ T + 0·00004555\ T^2$$

$$\frac{dq}{dt} = c = 0·232314 + 0·0000911\ T$$

$$\varphi_1 = (c)\,(2·30258)\log 10\ \frac{\tau_1}{492·66}$$

$$r = 164·57 - 0·0716\ T - 0·0002746\ T^2$$

$$\mu = 144 \left(\frac{778r}{\tau\dfrac{dp}{dt}}\right)$$

$$v = \mu + v_1$$

$$v_1 = ·0122903 + 0·0000874\ T$$

Volume of 1 pound of superheated CS_2 under standard conditions of pressure and temperature = 4.7189 cubic feet, and 1 pound weight of CS_2 gas is 2·6258 times the volume of an equal amount of air.

$$pv = 20·271\ \tau$$

k_p = ·1596 (176° F. — 374° F.). Regnault.
k_v = 1·33545 } Computed.
γ = 1·1958 }

Exponent of saturation curve, n = 1·058.

Boiling point, 115·88° F. { Thorpe. Freidburg.

Critical temperature, 504·5° F. Pressure, 978 pounds absolute.

ADIABATIC EXPANSION.

TEMPERATURE RANGE F°	PRESSURE RANGE LBS.	VALUES OF n FOR QUALITIES OF									
		100 per cent.	90 per cent.	80 per cent.	70 per cent.	60 per cent.	50 per cent.	40 per cent.	30 per cent.	20 per cent.	10 per cent.
265°—190°	120 31 to 9·097	1·1155	1·1002	1·0823	1·0611	1.0355	1·0038	·96355	·9095	.83518	.7157
190°—9 °	47·82 to 9·097	1·1292	1·1154	1·1099	1·0791	1·052	1·0230	·9818	·9240	·8402	.6987
205°—120°	58·55 to 15·98	1·1236	1·1077	1·0898	1·0675	1·0367	1·0059	·9578	·8969	·8036	·65095
Averages		1·1221	1·1078	1·0904	1·0692	1·0414	1·0109	·9677	·9101	·8293	·6885

x	n
50 per cent.—50 per cent.	—6·4214
70 per cent.—50 per cent.	—6·001
100 per cent.—50 per cent.	—6·65
Average	—6·35

$$x\, n^{-6{\cdot}36} = c$$

$$n = \sqrt[6{\cdot}36]{\frac{x}{c}}$$

THE IRON PILLAR OF DELHI.

An illustration of the famous iron pillar of Delhi, India, is given in a recent number of *Cassier's Magazine*, together with the following particulars of it:

The pillar is a solid shaft of wrought iron, 16 inches in diameter, and of a length that is variously reported. The total height above ground is 22 feet, including a capital of 3½ feet. Major G. A. Cunningham, R.E., C.S.I., Director-General of the Archæological Survey of India, reported in 1863 that the total length of the pillar is upward of 48 feet, and possibly 60 feet.

The lower diameter is 16·4 inches and the upper diameter 13·5 inches. The pillar contains about 80 cubic feet of metal and weighs about 17 tons. The metal was for a long time reputed to be bronze, owing probably to a curious yellowish shade on the upper part. A sample from near the base was analyzed by Dr. Murray Thompson and found to be pure malleable iron of 7·66 specific gravity. The metal is, of course, charcoal iron, made directly from the ore in small billets; but how it was welded up no one can tell, as no record exists of any early method of dealing with great masses of wrought iron.

An inscription, roughly cut or punched upon the column, states that Raja Dhara subdued a people in the Surdhu, named Vahlikos, and obtained with his own arm an undivided sovereignty on the earth for a long period. The date of the inscription has been referred to the third or fourth century after Christ; but on this authorities are at variance, as the style of writing is supposed by some to belong to a later period.

According to tradition, the Iron Pillar was erected by Bilan Deo, the founder of the Tomara dynasty, who was assured by a learned Brahmin that, as a part of the pillar had been driven so deep into the ground that it rested on the head of Vasuki, King of Serpents, who supports the earth, it was now immovable, and that dominion would remain in his family as long as the pillar stood. The Raja, doubting the truth of the Brahmin's statement, ordered the pillar to be dug up, when the foot was found to be wet with the blood of the serpent king. The pillar was again raised, but owing to the Raja's incredulity, no means could be found to fix it firmly, and it remained loose (dhila) in the ground, and this is said to have been the origin of the name of the ancient city of Delhi.

Mining and Metallurgical Section.

Stated Meeting, held March 28, 1903.

A Study of Alloys Suitable for Bearing Purposes.

BY G. H. CLAMER,
Vice-President Ajax Metal Company, Member of the Institute.

DISCUSSION.

(*Concluded from page 77.*)

DR. C. B. DUDLEY, Chemist to the Pennsylvania Railroad:—I have been very much interested in reading over the work done by Mr. Clamer, the results of which are given in the above paper, and I think he is to be congratulated. While it hardly seems possible to say that a finality has been reached in the study of bearing metal alloys, we are clearly of the opinion that Mr. Clamer's work in developing the plastic bronze is a decided step forward. His demonstration of the value in bearing metals of a diminution of tin and an increase of lead, and the means by which he accomplishes this successfully, must be regarded as valuable contributions to our knowledge of the subject. It was hoped that the plastic bronze might prove as great a mitigation of the hot-box trouble as the introduction of the lead lining did some years ago, and while positive tests do not seem to absolutely confirm this hope, it is not too much to say that plastic bronze is a decided improvement in this respect over any other bearing metal with which we are conversant. The value of the plastic bronze in the loss of metal by wear, and the slow wearing of the journal, seems to put it, taken all in all, ahead of any other bearing metal, and indeed ahead of the lead-lined bearing. It seems probable that further study, with the appliances now at hand, including especially the microscopic examination of metals and reliable testing-machines for determining rate of wear and friction, may in the future develop something better than anything at present known, but this does not detract from the very great value of the work done by Mr. Clamer.

MR. C. N. FORREST, Chemist to the Long Island Railroad Company:—An extensive study of the alloys of copper, tin and lead, etc., could hardly be attempted by the testing department of the ordinary railroad, and it is from such useful data as Mr. Clamer has presented that the standards of many roads have been adopted.

An alloy of practically the composition of Dr. Dudley's Ex. B. metal has been the standard bearing metal of the Long Island Railroad for a number of years, and clean, sound castings of this metal, properly finished and lined with ordinary lead and carefully inspected and tested before accepted, have made a record in the passenger service of this road which leaves little to be desired, as we now have practically no hot boxes on our cars. During the past year we used plastic bronze bearings, feeling that the composition was good, but chiefly on account of the lower cost.

I cannot, from a practical railroad service standpoint, quite agree with Mr. Clamer in his statement that the "first and foremost qualification is that the alloy have the best composition to make the bearings," and that "on this depend all the following essentials" (friction, wear on journal, etc.), although this is, of course, of very great importance. To the railroad the first desideratum is a bearing which will run cool—the life of the bearing is of secondary importance. The most perfect composition of the alloy is of little avail unless the mixture is uniform and clean, the bearing surface smooth and of the proper radius, and while these results should be obtained with alloys of theoretically the best composition, they are also obtained with alloys made from other formulas. Within reasonable limits the composition has little to do with causing or preventing hot boxes. With the same care in packing and mechanical details, the freedom from hot boxes depends almost entirely on the other points I have mentioned, and practical experiments have shown that bearings with several per cent. of zinc will run cool provided the casting is clean and sound, and the bearing surface true and smooth before it is lined.

I have no figures to show the life of the brasses on our road, but feel safe in saying that no brass remains in our passenger service long enough to wear out. Removal of wheels or axles, etc., necessitates the removal of the brasses, and it is impracticable to put the old brasses on new journals after the lead lining is gone, so that nearly all of the bronze portion of the brass goes into the scrap bin, which fact offsets to a great extent the improved wearing qualities of any special alloy.

In view of such service and practice, a slight improvement in the anti-frictional and wearing properties of a new alloy is not of sufficient advantage in itself to warrant any change of standards, and the chief attraction to the consumer remains in the lower cost of the new metal, which Mr. Clamer has not neglected, and rightly, to emphasize, and this will doubtless be at present the strongest argument in favor of plastic bronze.

The experience of the Long Island Railroad with plastic bronze bearings has not been sufficiently long to permit any statement as to the practical service of this alloy, but granting that it is possible to obtain castings of equal mechanical perfection with the new alloy, there appears to be no reason why it should not be as generally used as the older standards at the same cost, and more extensively so long as it is sold at a lower price.

Mr. Clamer's paper is a valuable contribution to our literature on alloys.

MR. CLAMER:—Mr. Forrest has probably not interpreted my meaning relative to the statement that the foremost qualification of the bearing alloy is that it have the proper composition, and on this depend all the other essentials.

It is very true that the best compositions often fail, owing to certain physical or mechanical defects, and the meaning I intended to convey is that the composition is fundamental. You cannot make a bad composition give good results, but you can make a good composition give bad results.

In discussing fracture, I confined myself to the characteristic structure of the alloys treated, and did not care to deal with the subject of segregations, etc., which are caused by improper foundry practice. Some years ago I investigated this point very thoroughly, and I do not wish to discount in any way the value attached to the examination of fracture of bearings, as I have long recognized the value of such inspection, and, in fact, we carry this out in our daily work; breaking one brass out of each heat cast. It does happen sometimes that segregations will occur in perhaps one brass in a flask, sometimes in a whole flask, and not in others; but, generally speaking, if the last flask is good the whole heat is good, owing to this being poured from the dullest metal.

I thoroughly agree with Mr. Forrest in his statement that the first desideratum is that the bearing will run cool, but I do not think there is any doubt but that the softer compositions will often prevent hot boxes by conforming to the irregularities, etc., to which, if the harder compositions were subjected, would cause abrasion and heating. There is no better example of this than the lead-lined bearing. In other words, the bearing which will stand the greatest amount of ill use is the one which will give the least trouble in service.

The item of wear is also an important factor, irrespective of the fact that the bearings are seldom worn out in service. It has been shown that eight bearings of good composition on a car will lose by wear under normal conditions, from 1 to 3 pounds in 25,000 miles of travel, and irrespective of the fact that what is left of the bearing is remelted and made into new bearings, the metal actually lost and unrecoverable in a year's operation is a considerable amount.

The item of wear is probably of higher importance in locomotive practice, as the journals are operated directly upon the brass, and not in contact with a lead lining, as is the case of car equipment. The importance of having a composition which will run cool in locomotive service is also, for this reason, of high importance.

APPENDIX.

The Goldschmidt Theory of Harmony.

BY JOSEPH W. RICHARDS.

Read at the meeting of the Physical Section of the Institute, January 22, 1902.
(*Concluded from p. 235.*)

THE LAW OF INTER-RELATION IN MUSIC.

The diatonic scale from c to $\bar{c}$ may be expressed numerically in two ways, either by giving the relative times of vibration (Z) corresponding to each note, that is, the relative number of vibrations per second, or by giving the relative wave lengths (l), that is, the relative lengths of vibrating strings giving the various tones.

	c	d	e	f	g	a	b	$\bar{c}$
$Z =$	1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2
$l = \frac{1}{Z} =$	1	$\frac{8}{9}$	$\frac{4}{5}$	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{3}{5}$	$\frac{8}{15}$	$\frac{1}{2}$

We may study each of these series to find their meaning in the harmonic numbers. We will take up first the ascending series.

Transposing the Z series so as to make $c = 0$ and $\bar{c} = \infty$, we obtain

	c	d	e	f	g	a	b	$\bar{c}$
$p = \frac{Z - 1}{2 - Z} =$	0	$\frac{1}{7}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	7	∞

Comparing this with the normal crystallographic series N_3, we note the absence of 3, and the interpolation of $\frac{1}{7}$ and 7. But $p = 3$ would correspond to $Z = \frac{7}{4}$, which is the vibration number of $b\flat$. Inserting this, we have

	c	d	e	f	g	a	$b\flat$	b	$\bar{c}$
$p =$	0	$\frac{1}{7}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	7	∞

The series is now symmetrical, with its middle point $g = 1$, which is the most important point of the series, next to the terminals, musically as well as crystallographically, for in music it is the "fifth," and is called the "dominant." This appellation has been carried over into crystallography.

An agreeable succession of notes is given by striking in series the following:

c		g		$\bar{c}$	:	$p =$	0				1				∞
c	f	g	a	$\bar{c}$	:	$p =$	0			$\frac{1}{2}$	1	2			∞
c	e	g	$b\flat$	$\bar{c}$	:	$p =$	0		$\frac{1}{3}$		1		3		∞
c	d	g	b	$\bar{c}$	:	$p =$	0	$\frac{1}{7}$			1			7	∞

The dominant, $p = 1$, plays in the development of crystal forms, as in harmonic tones, a prominent and a similar part: in music, for the developmentof the structure (Fortbildung der Tonarten); in crystallography, for the building up of secondary and tertiary zones.

The numbers $\frac{1}{7}$ and 7, corresponding to the tones d and b, do not fit into or form part of the normal N_3 series. They do not appear to belong normally to that series; and in reality they are not members of the harmonic combination c, g, $\bar{c}$ (C major), but of the next related combination g, $\bar{d}$, $\bar{g}$ (G major). Of this latter combination, $\bar{d}$ is the "dominant" or "quint," and b is the important element, the "third." These facts are known musically; proof of them from the standpoint of the "law of inter-relation" is as follows:

Take the vibration frequencies of the series from g to $\bar{g}$, and they are:

	g	a	$b\flat$	b	$\bar{c}$	$\bar{d}$	$\bar{e}$	$\bar{f}$	$\bar{g}$
$Z =$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{7}{4}$	$\frac{15}{8}$	2	$\frac{9}{4}$	$\frac{5}{2}$	$\frac{8}{3}$	3

Transposing, with $g = 0$, $\bar{g} = \infty$, and $p = \dfrac{Z - \frac{3}{2}}{3 - Z}$, we have

	g	a	$b\flat$	b	$\bar{c}$	$\bar{d}$	$\bar{e}$	$\bar{f}$	$\bar{g}$
$p =$	0	$\frac{1}{8}$	$\frac{1}{5}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	$\frac{7}{2}$	∞

The normal N_3 series, developed between g and $\bar{g}$, includes, therefore,

	g	b	$\bar{c}$	$\bar{d}$	$\bar{e}$	($c\sharp$)	$\bar{g}$
$p =$	0	$\frac{1}{3}$	$\frac{1}{2}$	1	2	(3)	∞

The tone $p = 3$ corresponds to $Z = \frac{21}{8}$, which is very nearly $c\sharp$. It is further to be observed that while b and d here become important members of the series, while they appear intruders in the series c, g, $\bar{c}$, yet, conversely, a, $b\flat$ and f, which are important members of the series *c*, *g*, $\bar{c}$, are intruders in this series. In fact, only *c*, *e* and *g* are common members of both combinations, being respectively 0, $\frac{1}{3}$, 1, of the *C* major combination and 0, $\frac{1}{2}$, 2, of the *G* major series; *f* and *a* are $\frac{1}{2}$ and 2 of the *C* major series, and *b* and *d* $\frac{1}{3}$ and 1 of the *G* major series.

The combination of the harmonic numbers 0, $\frac{1}{3}$, $\frac{1}{2}$, 1, 2 of the two series *c*, *g*, *c* and *g*, $\bar{d}$, *g*, give us all the notes of our diatonic scale. This scale is therefore not a harmonically developed whole, but is heterogeneous, composed of two simple series of like form superposed upon each other. These series contain all the harmonic numbers of an N_2 series, plus $\frac{1}{3}$ from the N_3 series, and therefore stand between N_2 and N_3 in development. It is also common in crystallography to find series occurring which stand in their development between two normal series, or which contain all of the elements of one series plus one or two of a higher.

The tones of the scale lacking to make up a full N_3 series are $\frac{2}{3}$, $\frac{3}{2}$ and 3. These would correspond in vibration frequencies in the series *c*, *g*, $\bar{c}$, to $Z = \frac{7}{5}$, $\frac{8}{5}$ and $\frac{7}{4}$, that is, to the tones *f*♯, *a*♭ and *b*♭. If we add these to the series *c*, *c*, we have

$N_3 : p =$	0	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{2}{3}$	1	$\frac{3}{2}$	2	3	∞
corresponding to $Z =$	1	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{7}{5}$	$\frac{3}{2}$	$\frac{8}{5}$	$\frac{5}{3}$	$\frac{7}{4}$	2
and the tones	*c*	*e*	*f*	*f*♯	*g*	*a*♭	*a*	*b*♭	$\bar{c}$

This series approximates to our chromatic scale, but is not, like it, an aggregate, but is a harmonically developed whole. It is not likely that our present style of music could use such a complicated scale. Our music has developed polyphonically, by the succession of accords from the series 0, $\frac{1}{3}$, $\frac{1}{2}$, 1, 2, 3, ∞, arranged upon varying ground-tones. The ground-tones themselves stand in a simple relationship, being first the harmonic numbers 0, ∞, then 0, 1, ∞, then 0, $\frac{1}{2}$, 1, 2, ∞. For such simple chords based on such simple progressions of the ground-tones of the chords, the differentiation within the octave up to full N_3 is too complicated. The harmonic correllation of the progressive ground-tones gives, together with the variations of the chords themselves, as great a variety of construction as we care to make use of.

[Where part-singing has not developed, and no accords exist, but only the sequence of notes, the complication within the octave may reach N_3 and even surpass it. Such one-part music has highly developed in the Orient, as among the Arabians, Indians and Japanese. Dr. Goldschmidt has observed, by studying this one-part music in its home, in Tunis, India and Japan, that where our several-part music is introduced it destroys the delicate refinements of the one-part music. The process is going on in Japan. Japanese music appears dry to us, because there are no chords, and not pure, because it has intermediate tones which our simplified development of tonal succession does not have. On the other hand, to the musically cultivated Japanese our music appears crude in its tonal successions, since the refinements of development between the tones are lacking. Our chords give him too much music at once, and spoil for him the enjoyment of his delicate, finely modulated tonal successions. Thereby it is comprehensible that he likes his own music better. This view of the subject also explains why the Japanese melodies do not stand a many-part arrangement without losing thereby their character. Because of the chords, the tonal succession alters its nature a little, and the music is thereby no longer the same: it has become European.]

A *chord* is a group of harmonic tones sounding simultaneously. *Sequence* is the same sounding in succession. The former may be called a *standing* chord, and designated thus—$c, f, a, \bar{c}$; the latter may be called a *progression*, and designated thus—$c\text{-}f\text{-}a\text{-}\bar{c}$. Certain chords are particularly pleasing to the ear, and harmonically particularly important for the construction of musical compositions; we call them "*principal chords*."

Chords are designated by the letters of their tones or by the harmonic numbers (p) and the ground-tone to which the numbers refer. Thus we write

$$\begin{array}{llllll} c & e & g = 0 & \tfrac{1}{3} & 1 & (c) \\ g & b & d = 0 & \tfrac{1}{3} & 1 & (g) \end{array}$$

Further, the same chord may be differently interpreted, as being one combination of harmonic numbers on one ground-tone, or a different combination on another ground-tone. Thus

$$\begin{array}{ccccccc} c & e & g = 0 & \frac{1}{3} & 1 & (c) \\ g & c & \bar{e} = 0 & \frac{1}{2} & 2 & (g) \end{array}$$

Taking the series of harmonic numbers

$$p = 0 \quad \tfrac{1}{3} \quad \tfrac{1}{2} \quad 1 \quad 2 \quad 3 \quad \infty$$

the principal chords are the following:

0			1			∞
0		$\frac{1}{2}$		2		∞
0	$\frac{1}{3}$		1			∞
0	$\frac{1}{3}$		1		3	∞
0	$\frac{1}{3}$			2		∞

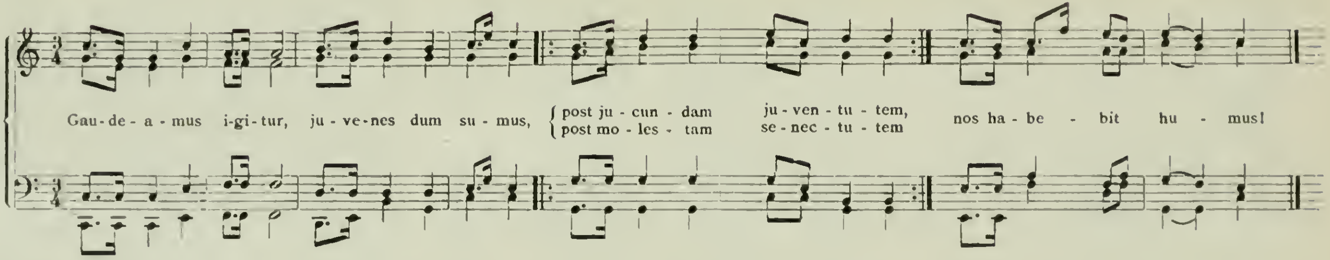
Studying these chords, for convenience, in the octave *c*, *g*, $\bar{c}$, we may say of them:

0, 1, ∞ = c, g $\bar{\mathbf{c}}$ is the crystallographic normal series N_1, the empty fifth. It is the foundation of harmonic sub-division; however, only a double tone. The most important combination crystallographically.

0, $\frac{1}{2}$**, 1, 2, ∞ = c-f-g-a-**$\bar{\mathbf{c}}$ is not a standing chord, but is a melodious progression. It is important because it is the principal progression upon which the ground-tones move in that sequence of chords which form the piece of music. This series is not a good standing accord because of the nearness of *g* to *f* and *a*, producing discord. It would be the normal series N_2.

0, $\frac{1}{2}$**, 2, ∞ = c, f, a,** $\bar{\mathbf{c}}$ is the normal series N_2 without the dominant 1 = *g*; *f*, *g* and *a* are too close together to agree in a standing accord; leaving *g* out, the chord is melodious.

0, $\frac{1}{3}$**, 1, ∞ = c, e, g,** $\bar{\mathbf{c}}$ is called the *major chord*. It is, according to the harmonic numbers, the next simple group. In this chord the tones are not near enough to cause interference; therefore, this chord is superior to 0, $\frac{1}{2}$, 1, 2, ∞ as a standing chord, but not as a progression. Further, 0, $\frac{1}{2}$, 2, ∞ (*c*) = *c*, *f*, *a*, $\bar{c}$ is harmonically identical with *f*, *a*, *c*, $\bar{f}$ = 0, $\frac{1}{3}$, 1, ∞ (*f*); therefore, the former must also be a major chord, only lowered a fifth to another ground-tone. The major chord corresponds therefore to both 0, $\frac{1}{2}$, 2, ∞ and 0, $\frac{1}{3}$, 1, ∞. That increases its harmonic importance. The


Gau-de-a-mus i-gi-tur, ju-ve-nes dum su-mus,
post ju-cun-dam ju-ven-tu-tem,
post mo-les-tam se-nec-tu-tem
nos ha-be-bit hu-mus!

													post	ju -	cun	dam	ju -	ven -	tu -	tem							
Gau -	de -	a -	mus	i -	gi -	tur	ju -	ve -	nes	dum	su -	mus	post	mo -	les	tam	se -	nec -	tu -	tem	nos	ha -	be -	bit	hu	-	mus
c	g	g	c	a	a	a	b	c	d	b	ce	c	b	c	d	d	e	c	d	d	c	b	af	ed	c	d	c
g	e	e	g	f	f	f	g	g	g	g	g'	g	g	a	b	b	c	g	g	g	g	g	f ··	aa	c	b	c
c	c	c	e	f	f	f	d	d	d	d	eg	e	g	g	g	g	g	e	b	b	e	c	a ·	fa	g	f	e
c	c	c	e	f	f	f	d	e	b	g	c'	c	g	g	g	g	c	c	g	g	e	c	f ·	df	g	g	c
o 1	o⅓1	o⅓1	o⅓1	o⅓	o⅓	o⅓	o⅓1	o½12	o⅓1	o⅓1	o⅓1	o⅓1	o⅓	o½2	o⅓1	o⅓1	o⅓1	o⅓1	o⅓1	o⅓1	o⅓1	o⅓2	o⅓	·o⅓2	o⅓1	o⅓13	o⅓1
c	c	c	c	f	f	f	g	g	g	g	c	c	g	c	g	g	c	c	g	g	c	g	f	·f	c	g	c

c f g
o ½ 1
c

c g
o 1
c

c f g
o ½ 1
c

c

major chord is the most important chord in rising harmony—perhaps even of all music.

$0, \frac{1}{3}, 1, 3, \infty$ = c, e, g, b, $\bar{\text{c}}$, the symmetrically completed major chord, is harmonic both as a chord and as a sequence. The introduction of $b = 3$ makes the chord fuller, the harmony more complete. In fact, we find this chord in four-part musical pieces at particularly emphatic or important places.

$0, \frac{1}{3}, 2, \infty$ = c, e, a, $\bar{\text{c}}$ is a minor chord, for it is harmonically identical with $e, c, a = 0, \overline{\tfrac{1}{3}}, \bar{1}\ (e)$ in descending harmony, as will be explained in considering the descending wave lengths from c to $\bar{c}$. Therefore, $0, \frac{1}{3}, 2$ is the interpretation of a minor chord where it occurs amongst the chords of a major piece, and $0, \overline{\tfrac{1}{3}}, \bar{1}$ is the interpretation of the same chord in minor compositions.

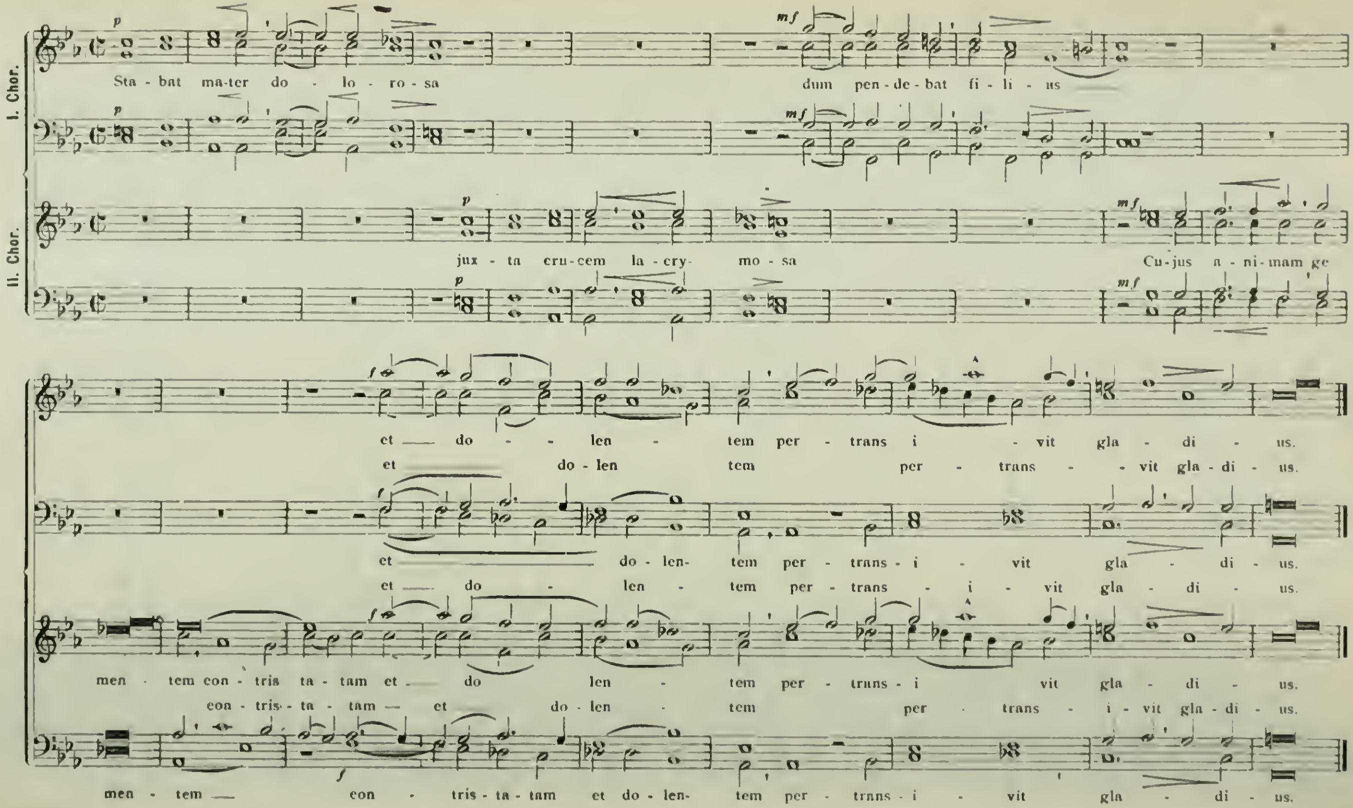
We have so far considered the numerical series from c to $\bar{c}$ in the sense of the *ascending* vibration numbers, and deduced from them the corresponding harmonic numbers and discussed their relationships, particularly in the building up of chords; but the reciprocals of these numbers, that is, the relative wave lengths, have an equal claim to consideration, and may equally serve as the basis of a discussion of the harmonic numbers represented. We have found that the simple combinations of harmonic numbers derived from the *ascending* numbers, that is, the *rising harmony*, give us the principal major chords and one subordinate minor chord. We will find that an exactly similar treatment applied to the *descending* series of *decreasing* wave lengths, from c to $\bar{c}$, will give for the simple combination of the harmonic numbers derived therefrom the principal minor chords and one subordinate major chord.

The wave lengths are the reciprocals of the vibration numbers, and are:

$$\begin{array}{lcccccccc} & c & d & e & f & g & a & b & \bar{c} \\ Z = \dfrac{1}{\bar{Z}} = & 1 & \frac{8}{9} & \frac{4}{5} & \frac{3}{4} & \frac{2}{3} & \frac{3}{5} & \frac{8}{15} & \frac{1}{2} \end{array}$$

and the corresponding p series (designated as $\bar{p}$ to distinguish from the reciprocal tones in rising harmony):

$$\begin{array}{lcccccccc} & c & d & e & f & g & a & b & \bar{c} \\ \bar{p} = & \bar{\infty} & \overline{\tfrac{7}{2}} & \overline{\tfrac{3}{2}} & \bar{1} & \overline{\tfrac{1}{2}} & \overline{\tfrac{1}{4}} & \overline{\tfrac{1}{14}} & 0 \end{array}$$


I. Chor.
II. Chor.
Sta - bat ma-ter do - lo - ro - sa
dum pen-de-bat fi - li - us
jux - ta cru-cem la - cry- mo - sa
Cu-jus a - ni-mam ge
et — do - - len - tem per - trans i - vit gla - di - us.
et — do - len tem per - trans - - vit gla - di - us.
et — do - len- tem per - trans - i - vit gla - di - us.
et — do - len - tem per - trans - i - vit gla - di - us.
men - tem con - tris ta - tam et — do len - tem per - trans - i vit gla - di - us.
con - tris - ta - tam — et do - len - tem per - trans - i - vit gla - di - us.
men - tem — con - tris - ta - tam et do - len- tem per - trans - i - vit gla - di - us.
p
mf
f

Sta bat - ma ter do - lo ro - sa							
Jux - ta cru - cem la - cry - mo sa	Dum pen-de - bat fi - li . us	Cu - jus	a - ni - mam ge - men tem	Con-tris-	ta · tam et · · do · · len · · tem	Per - tran - si - vit	gla - di - us
c d e♭ e♭ e♭ e♭ d♭ c	g f e♭ d d c b c	e e	f f a♭ g f e♭	e♭ e♭	e♭ e♭ e♭ a♭ · · g f e♭ f f d♭ c	e♭ f g · · a♭ · g f	e f e f
g b♭ c c b♭ c b♭ g	c c c b♭ b♭ a♭ g g	c c	c c c c d♭ c	a♭ g	c b♭ c e · · c f c b♭ a♭ ·g a♭	c · d♭ e♭ d♭ c b♭ a b	c c c c
e f a♭ a♭ g a♭ f e	g a♭ g g f e♭ d c	g g	a♭ a♭ f g a♭ a♭	c b♭	a♭ g a♭ a♭ gf g a♭ g f · b e♭	· · · · · e♭ f f	g a♭ g a
c b♭ a♭ a♭ e♭ a♭ b♭ c	c f c g b♭ f g c	c c	f f f e♭ d♭ a♭	e♭ e♭	· · f f · · e♭ d♭ c d♭ d♭ b a♭	a♭ · b♭ · · c d♭ d♭	c · c f
0⅓1 0⅓1 0⅓1 0⅓1 0⅓1 0⅓1 0¼1 0⅓1	01 0⅓2 0⅓2 0⅓2 0⅓1 0⅓12 0⅓1 01	0⅓1 0⅓1	0⅓2 0⅓2 0⅓2 0⅓2 0⅓1 0⅓1	0⅓1 1⅓1	0⅓1 0⅓1 0⅓12 0⅓2 x 0⅓2 0⅓1 0⅓2 0⅓2 0⅓1 02 . 0⅓1	0⅓1 · 0⅔2 · · 0⅓1 0⅓1 0⅓2	0⅓1 0¼1 0⅓1 0⅓1
c b♭ as♭ as♭ e♭ a♭ b♭ c	c a♭ e♭ b♭ b♭ a♭ g c	c c	a♭ a♭ a♭ e♭ d♭ a♭	a♭ e♭	a♭ e♭ a♭ a♭ e♭ d♭ e♭ d♭ d♭ d♭ a♭	a♭ · d♭ · · a♭ d♭ d♭	c f c
e♭ a♭ b♭ c	e♭ g a♭ b♭ c	c	a♭ d♭ e♭	a♭ a♭	a♭ d♭ e♭	a♭ d♭ e♭	f c
0 ½ 1 2	0 ⅓ ½ 1 2	⅓	0 ½ 1	0 1	0 ½ 1	0 ½ 1	0 1
e♭	e♭	a♭	a♭	a♭	a♭	a♭	f
e♭			a♭				f

a♭ e♭ f

0 1 2

a♭

$\bar{p} = \overline{\infty}$, $\bar{1}$, etc., we will call the "*falling* harmonic numbers," as distinguished from $p = \infty$, 1, etc., the "*rising* harmonic numbers." In the $\bar{p}$ series, $f = \bar{1}$ and is the falling dominant, the falling quint. The harmonic $\bar{p}$ numbers do not correspond, taken, as they are, directly from the scale, to the p series $= 0, \frac{1}{3}, \frac{1}{2}, 1, 2, \infty$. What tones would such a series correspond to in falling harmony? We would find them as follows:

Putting	$\bar{p} = \overline{\infty}$	$\bar{3}$	$\bar{2}$	$\bar{1}$	$\overline{\frac{1}{2}}$	$\overline{\frac{1}{3}}$	0
Then	$Z = \frac{1}{Z} = \bar{Z} = 1$	$\frac{7}{8}$	$\frac{5}{6}$	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{5}{8}$	$\frac{1}{2}$
corresponding to	$Z = 1$	$\frac{8}{7}$	$\frac{6}{5}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{8}{5}$	2
and the tones	*c*	(d^1)	*e*♭	*f*	*g*	*a*♭	$\bar{c}$

[N. B.—The tone $d^1 = \frac{8}{7}$ is not on the piano-forte, but is $\frac{1}{56}$ of a tone above *d*. It can be brought out, however, on a violin.]

We have, therefore, the elements of the harmonic series corresponding to the series in rising harmony, but in place of $0, \frac{1}{3}, \frac{1}{2}, 1, 2, \infty = c, e, f, g, a, \bar{c}$, as in *rising* harmony, we have $\overline{\infty}, \bar{2}, \bar{1}, \overline{\frac{1}{2}}, \overline{\frac{1}{3}}, 0 = c$, *e*♭, *f*, *g*, *a*♭, $\bar{c}$ in *falling* harmony. The former are based on the *rising* interval; the latter on the *falling* interval. For instance, for $c = 1$, $g = \frac{3}{2}$ is the *rising* quint; so is, reciprocally, $f = \frac{2}{3}$ the *falling* quint, that is, the tone whose rising quint is $c = 1$.

As the harmony of the upward developing tones is controlled by the rising harmonic numbers p, so is the harmony of the downward developing tones controlled by the falling harmonic numbers $\bar{p}$. It turns out that the *rising* harmony is that which we call *major*, and the *falling* harmony that which we call *minor*. Thus we have

Rising harmonic series						
= Major series:	$p = 0$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	∞
e.g., *C* major series:	*c*	*e*	*f*	*g*	*a*	$\bar{c}$
Falling harmonic series						
= Minor series:	$\bar{p} = 0$	$\overline{\frac{1}{3}}$	$\overline{\frac{1}{2}}$	$\bar{1}$	$\bar{2}$	$\overline{\infty}$
e.g., *C* minor series:	$\bar{c}$	*a*♭	*g*	*f*	*e*♭	*c*

Between rising and falling, major and minor harmony, there is full reciprocality. Major tones are based on the *increasing* number of vibrations (Z); minor tones on the *decreasing* wave lengths (l); the ones are the reciprocals of the others. Every harmonic phenomenon in major has its counterpart in minor. The major character lies in the *upward* development; the minor character in the *downward* development. May not the psychological differences of these two styles of music have some foundation in this fact?

We have discussed the separate chords in rising harmony; we will now discuss the corresponding ones in falling harmony.

$\mathbf{0, \bar{1}, \bar{\infty} = \bar{c}, f, c}$, the normal crystallographic series N_1, the falling empty quint. But $c, f = 0, \bar{1}$ ($\bar{c}$) is harmonically identical with $f, \bar{c} = 0, 1$ (f). Therefore, 0, 1 is harmonically equivalent to $0, \bar{1}$.

$\mathbf{0, \overline{\tfrac{1}{2}}, \bar{1}, \bar{2}\ \bar{\infty} = c, g, f, e\flat, c}$ is not a standing chord, but is a melodious progression. It is important because it is the principal progression upon which the ground-tones move in that sequence of chords which occur in a piece of minor music. This series is not a good standing accord, because of the nearness of g, f and $e\flat$ producing discord. It would be the normal series N_2. $0, \overline{\tfrac{1}{2}}, \bar{2}, \bar{\infty} = \bar{c}, g, e\flat, c$ is the normal series N_2 in falling harmony without the dominant $f = 1$. f g, and $e\flat$ are too close together to agree in a standing chord; leaving f out, the chord is melodious.

$\mathbf{0, \overline{\tfrac{1}{3}}, \bar{1}, \bar{\infty} = \bar{c}, a\flat, f, c}$ is called the *minor chord.* It is, according to the harmonic numbers, the next simple group. In this group the tones are not near enough to cause interference. Therefore, this chord is superior to $0, \overline{\tfrac{1}{2}}, \bar{1}, \bar{2}, \bar{\infty}$ as a standing accord, but not as a progression. Further, $0, \overline{\tfrac{1}{2}}, \bar{2}, \bar{\infty}$ ($\bar{c}$) $\bar{c}, \bar{g}, e\flat, c$ is harmonically identical with $\bar{g}, e\flat, c, g = 0, \overline{\tfrac{1}{3}}, \bar{1}, \bar{\infty}$ ($\bar{g}$); therefore, the former must also be a minor chord, only raised a fifth to a new ground-tone. The minor chord corresponds, therefore, to both $0, \overline{\tfrac{1}{2}}, \bar{2}, \bar{\infty}$ and $0, \overline{\tfrac{1}{3}}, \bar{1}, \bar{\infty}$. That increases its harmonic importance. The minor chord is the most important chord of falling harmony; it rivals the major chord in importance.

$\mathbf{0, \overline{\tfrac{1}{3}}, 1, 3, \bar{\infty} = \bar{c}, a\flat, f, d^1, c}$, the symmetrically completed minor chord, is harmonic both as a chord and a sequence.

The introduction of $d^1 = \overline{3}$ makes the chord fuller, the harmony richer. d^1 is, however, only $\frac{1}{56}$ tone above d, and cannot be produced on a piano.

$\mathbf{0, \tfrac{1}{3}, 2, \infty = c, a\flat, e\flat, c}$ is a major chord, for it is harmonically identical with $a\flat, c, e\flat = 0, \frac{1}{3}, 1$ $(a\flat)$ in ascending harmony. This major chord is to be interpreted as $0, \overline{\tfrac{1}{3}}, 2$ when it occurs interspersed between the chords of a composition in falling harmony (minor music), and as $0, \frac{1}{3}, 1$, where it occurs in pieces of rising harmony (major compositions).

Progression upon varying ground-tones is the key to the development of a musical composition. This is to say, that the chords $0\ 1$, $0\ \overline{1}$, $0\ \tfrac{1}{2}\ 2$, $0\ \overline{\tfrac{1}{2}}\ \overline{2}$, $0\ \tfrac{1}{3}\ 1$, $0\ \overline{\tfrac{1}{3}}\ \overline{1}$, $0\ \tfrac{1}{3}\ 1\ 3$, $0\ \tfrac{1}{3}\ 2$, $0\ \tfrac{1}{3}\ 2$, which are the principal ones of the normal series N_3, may be based on, or have for their ground tones c, e, f, g, a or $\overline{c}$ in major music, or $\overline{c}, a\flat, g, f, e\flat$ or c in minor music, either one of these notes being the 0, or ground-tone, of the chord, and between it and its octave the harmonic development to ∞ or $\overline{\infty}$ may subsist and the notes corresponding to the intermediate members of the chord be determined.

Progression of the ground-tones, however, does not take place haphazard, but is determined by the same law of development which determines the harmonies of a chord. Given a chord in the series

$$\begin{array}{rcccccc} p = & 0 & \tfrac{1}{3} & \tfrac{1}{2} & 1 & 2 & \infty \\ \text{or } \overline{p} = & 0 & \overline{\tfrac{1}{3}} & \overline{\tfrac{1}{2}} & \overline{1} & \overline{2} & \overline{\infty} \end{array}$$

then the progression of the ground-tones passes preferably to ∞ or $\overline{\infty}$, to 1 or $\overline{1}$, to $\frac{1}{2}$ and 2 or $\overline{\tfrac{1}{2}}$ and $\overline{2}$, or to $\frac{1}{3}$ or $\frac{1}{3}$, which order is the order of relative importance of these derived tones. We have thus, essentially, three principal varieties of progression of the ground-tones, viz., to the octaves, to the dominants, to the intermediate tones.

Progression upon the octaves simply repeats the chords higher or lower in the scale.

Progression upon the dominant fills in our diatonic scale with notes which are lacking in the primary N_3 scale based on *c*. It is most important for the building up of our tonic system.

Progression upon the intermediate tones, chiefly ascending on $p = \frac{1}{2}, 2$, or falling on $p = \frac{1}{2}, \overline{2}$, subordinately upon the higher numbers $p = \pm \frac{1}{3}, 3$, is the field of detail concerning the composition of musical pieces the choice of which—their alternations, symmetrical arrangement, or even peculiarities of arrangement—constitutes the characteristics of the composition and often marks the individuality of the composer.

KEY TO THE CHORDS.

MAJOR CHORDS.

Harmonic numbers rising	$p = 0$	$(\frac{1}{7})$	$(\frac{1}{4})$	$\frac{1}{3}$	$\frac{1}{2}$	1	$(\frac{3}{2})$	2	3	∞
	c	*d*	e♭	e	f	g	a♭	a	*b♭*	c
	c♯	*d♯*	*e*	*e♯*	*f♯*	*g♯*	*a*	*a♯*	*b*	*c♯*
	d♭	*e*	*f♭*	*f*	*g♭*	*a♭*	*a*	*b♭*	*c♭*	*d♭*
	d	*e♯*	f	f♯	g	a	b♭	b	*c*	d
	d♯	*f*	*f♯*	*g*	*g♯*	*a♯*	*b*	*c*	*c♯*	*d♯*
	e♭	*f*	*g♭*	*g*	*a♭*	*b♭*	*b*	*c*	*d♭*	*e♭*
	e	*f♯*	g	g♯	a	b	c	c♯	*d*	e
	f	*g*	a♭	a	b♭	c	d♭	d	*d♯*	f
	f♯	*g♯*	*a*	*a♯*	*b*	*c♯*	*d*	*d♯*	*e*	*f♯*
	g♭	*a♭*	*a*	*b♭*	*b*	*d♭*	*d*	*e♭*	*e*	*g♭*
	g	*a*	b♭	b	c	d	e♭	e	*f*	g
	g♯	*a♯*	*b*	*c*	*c♯*	*d♯*	*e*	*e♯*	*f♯*	*g♯*
	a♭	*b♭*	*c♭*	*c*	*d♭*	*e♭*	*e*	*f*	*g♭*	*a♭*
	a	*b*	c	c♯	d	e	f	f♯	*g*	a
	a♯	*c*	*c♯*	*d*	*d♯*	*e♯*	*f♯*	*g*	*g♯*	*a♯*
	b♭	*c*	*d♭*	*d*	*e♭*	*f*	*g♭*	*g*	*a♭*	*b*
	b	*c♯*	d	d♯	e	f♯	g	g♯	*a*	b
	c	d	*e♭*	e	f	g	a♭	a	*b*	c
Harmonic numbers falling	$\bar{p} = \bar{\infty}$	$\bar{3}$	$\bar{2}$	$\overline{(\frac{3}{2})}$	$\bar{1}$	$\overline{\frac{1}{2}}$	$\overline{\frac{1}{3}}$	$\overline{\frac{1}{4}}$	$\overline{\frac{1}{7}}$	$\bar{0}$

MINOR CHORDS.

In order to facilitate the dissection and analysis of musical compositions according to the principles so far developed, it is convenient to have a tabular arrangement of the different chords, giving the designation of each tone when considered in any chord based on any ground tone, either in rising or in falling harmony. The following is an anglicized copy of the table constructed by Dr. Goldschmidt.

IDENTIFICATION OF A CHORD BY MEANS OF THE KEY.—The key gives us in the right-hand direction the major harmonies, characterized by the harmonic numbers

$$p = 0 \qquad (\tfrac{1}{4}) \qquad \tfrac{1}{3} \qquad \tfrac{1}{2} \qquad 1 \qquad 2 \qquad 3 \qquad \infty$$

taken in the left-hand direction the minor harmonies, characterized by

$$\bar{p} = 0 \qquad (\overline{\tfrac{1}{4}}) \qquad \overline{\tfrac{1}{3}} \qquad \overline{\tfrac{1}{2}} \qquad \bar{1} \qquad \bar{2} \qquad \bar{3} \qquad \bar{\infty}$$

We may, therefore, read off for any chord its harmonic numbers according to the ground-tone chosen. Every chord, however, will be found to have *four interpretations*—two in major harmony and two in minor harmony. The major chord *c*, *e*, *g*, for instance, may be regarded either as

$$\left.\begin{array}{llll} c\ e\ g = 0\ \tfrac{1}{3}\ 1 & \text{based on ground-tone} & c = 0\ \tfrac{1}{3}\ 1\ (c) \\ g\ c\ e = 0\ \tfrac{1}{2}\ 2 & \text{“ \quad “ \quad “ \quad “} & g = 0\ \tfrac{1}{2}\ 2\ (g) \end{array}\right\} \begin{array}{l}\text{rising or}\\ \text{major.}\end{array}$$

$$\left.\begin{array}{llll} e\ c\ g = 0\ \overline{\tfrac{1}{3}}\ 2 & \text{“ \quad “ \quad “ \quad “} & e = 0\ \overline{\tfrac{1}{3}}\ \bar{2}\ (e) \\ g\ e\ c = 0\ \tfrac{1}{4}\ \bar{1} & \text{“ \quad “ \quad “ \quad “} & g = 0\ \overline{\tfrac{1}{4}}\ \bar{1}\ (g) \end{array}\right\} \begin{array}{l}\text{falling or}\\ \text{minor.}\end{array}$$

As another instance, the minor chord *a*, *f*, *d* may be interpreted as either

$$\left.\begin{array}{llll} a\ f\ d = 0\ \overline{\tfrac{1}{3}}\ \bar{1} & \text{based on ground-tone} & a = 0\ \overline{\tfrac{1}{3}}\ \bar{1}\ (a) \\ d\ a\ f = 0\ \overline{\tfrac{1}{2}}\ \bar{2} & \text{“ \quad “ \quad “ \quad “} & d = 0\ \overline{\tfrac{1}{2}}\ \bar{2}\ (d) \end{array}\right\} \begin{array}{l}\text{falling or}\\ \text{minor.}\end{array}$$

$$\left.\begin{array}{llll} f\ a\ d = 0\ \tfrac{1}{3}\ 2 & \text{“ \quad “ \quad “ \quad “} & f = 0\ \tfrac{1}{3}\ 2\ (f) \\ d\ f\ a = 0\ \tfrac{1}{4}\ 1 & \text{“ \quad “ \quad “ \quad “} & d = 0\ \tfrac{1}{4}\ 1\ (d) \end{array}\right\} \begin{array}{l}\text{rising or}\\ \text{major.}\end{array}$$

The question thus arises, what governs the interpretation in any given case; that is, which of the four possible interpretations shall be given any given combination or chord? The conclusions on this point arrived at by Goldschmidt are as follows:

(1) The simplest interpretation is primarily the most probable one. As a rule, *c*, *e*, *g* is to be regarded as $0, \frac{1}{3}, 1$ (*c*); *a*, *f*, *d* as $0, \overline{\frac{1}{3}}, \overline{1}$ (*a*).

(2) A homogeneous piece of music is to be regarded as either in rising harmony (major) or in falling harmony (minor). If the major chords predominate, the rising interpretation is to be preferred; if the minor chords predominate, the falling interpretation is to be preferred. If major and minor chords are equally present, then either a minor or a major interpretation may be given to the piece.

(3) Throughout a composition, or at least a completed part of the same, the one interpretation chosen must be adhered to; no change can be made inside such a part.

(4) If, with a major interpretation, minor chords occur interspersed between the major chords $0, \frac{1}{3}, 1$, they are in general to be regarded as the major chords $0, \frac{1}{3}, 2$, or, exceptionally, as $0, \frac{1}{4}, 1$. If, with a minor interpretation, major chords occur interspersed between the minor chords $0, \overline{\frac{1}{3}}, \overline{1}$, they are in general to be regarded as the minor chords $0, \overline{\frac{1}{3}}, \overline{2}$, or, exceptionally, as $0, \overline{\frac{1}{4}}, \overline{1}$.

The foundation of these rules lies in the fact that the ground tone assigned to the chord varies with the interpretation given to it. But the ground-tones stand in relation to each other; their progression is the progressive harmony of the composition. If the above rules are adhered to, it will be found that the ground-tones are related to each other according to simple progressions of harmonic numbers, such as on $0, \frac{1}{2}, 1, 2$, or $0, \overline{\frac{1}{2}}, \overline{1}, \overline{2}$, and, rarely, on $0, \frac{1}{3}, \frac{1}{2}, 1, 2$. If the rules given are not adhered to, this regularity of progression of the ground-tones will be interfered with or obliterated. This fact is the justification for the rules of interpretation given.

As examples of the application of Goldschmidt's method, we reproduce from his monograph the analysis of a very simple well-known piece, the "Gaudeamus Igitur," and that of Palestrina's "Stabat Mater," whose intricacies Helmholtz had declared to be incomprehensible from the standpoint of musical science.

Notes and Comments.

CROOKES ON ATOMIC FOG.

Prof. Sir William Crookes, before the International Chemical Congress in Berlin, recently, dealt with the possibility of reducing all the elements of matter to one, and ultimately finding this resolvable into a single form of energy. The subject was "Modern Views on Matter—the Realization of a Dream." Sir William cited the utterances of Sir Humphrey Davy and Faraday as anticipating the possibility of reducing the elements to simpler bases, spoke of the significance of the Röntgen rays and Becquerel rays, and the experiments of Curie and others, and said :

"All these observations find internal connection in the discovery of radium, which is probably the basis of the coarser chemical element. Probably masses of molecules dissolve themselves into the ether waves of the universe, or into electrical energy. Thus we stand on the border line where matter and force pass into each other. In this borderland lie the greatest scientific problems of the future. Here lie the final realities, wide-reaching and marvelous.

"The nineteenth century saw the birth of new views regarding the nature of atoms, electricity and ether While our views about the composition of the matter are generally satisfactory to-day, will that be the case at the end of the twentieth century ? Do we not again see that our investigations have only a temporary value ? Will we be content to see matter dissolving into a multitude of revolving electrodes? Such a mysterious dissolution of atoms appears to be universal. It occurs when a piece of glass is rubbed with silk. It is present in sunshine, in a raindrop, in lightning, in a flame, in a waterfall, and in the roaring sea. Although the whole range of human experience is too short to form a parallax whereby we can foretell the disappearance of matter, nevertheless it is possible that formless nebulæ will again prevail when the hour glass of eternity has run out."—*Electrical World.*

RECOVERY OF TIN FROM TIN-SCRAP.

Some interesting details relating to the recovery of tin from tin-scrap have recently been published in the *Zeitschrift f. Elektrochemie.* In Germany, several works have been built and operated for carrying out this procedure the largest of these being that of Goldschmidt, at Essen, where 50 to 60 tons of tin-scrap are reported to be treated per day. The difficulty of obtaining an adequate supply of raw material has hindered the development of other works, and the anonymous writer of the article we are discussing hints that the supply of tin-scrap is monopolized by one or two of the larger works. The processes used for recovering the tin are based upon the use of the scrap as anode material, in a bath containing sodium chloride and hydrate, or in one containing hydrochloric acid. The advantage of the former is that less iron goes into solution, but against this there is the lower efficiency of the process and the more spongy nature of the deposit obtained at the kathode. The failure to produce directly metallic tin is one of the chief difficulties in the operation of both processes, for considerable losses occur in smelting and refining the spongy deposit obtained at the kathode. Under certain conditions metallic tin can be obtained in the electrolytic bath, and Pfanhauser, in the issue of the *Zeitschrift f. Elektrochemie* for January 16th, has stated his opinion that the avoidance of formation of sponge is simply a question of maintaining the *concentration of the tin salt solution* in the neighborhood of the kathode. This condition would appear to be difficult to attain in the works treating tin-scrap on an industrial scale, and the problem of producing metallic tin at the kathode is complicated further, by the slow but gradual increase of impurities in the electrolyte. A new works for the treatment of tin-scrap has recently been built at Pfaffstätten, near Vienna, and an electrolytic process for recovering tin from slags is also reported to be in operation at Tostedt, in Germany.—*Scientific American Supplement.*

BAUXITE AND ITS USES.

The *Elektrochemische Zeitschrift* contains a useful reference article by Dr. H. Lienau on bauxite. This mineral is the chief source of the commercial aluminum produced by the electrolytic processes, and although many attempts have been made, and are still being made, to replace it by some cheaper raw material, these attempts hitherto have beed unsuccessful. Natural deposits of bauxite occur in France, Germany, Ireland, and the United States, those of the department Var in Southern France being at present the most extensively worked. In 1896 the district produced 29,620 tons, and in 1901, 65,000 tons, of which total 55,000 tons were exported to other countries. After a reference to the geological formation in which bauxite occurs and to the varying composition of the deposits, the author describes the various processes which have been worked at one time or another for extracting aluminum or its compounds from this source. The first patented process dates from 1858, and had for its object the extraction of aluminum hydrate from red bauxite. The demand by paper and color manufacturers for a cheaper source of aluminum sulphate than the alums turned attention to the direct production of aluminium sulphate from bauxite, but the efforts to produce this salt, free from iron, from red bauxite, have not been completely successful. The utilization of bauxite for the electrometallurgical production of aluminum is a comparatively recent development, but very large quantities of the mineral are now being used in aluminum reduction works. The author surmises from this fact that bauxite is being employed directly in the electrolytic baths, and that the troublesome and costly process by which alumina was first extracted from the raw bauxite is now being dispensed with.

[This surmise is most probably erroneous. Bauxite is now being refined in the electric furnace, on the large scale, for the production of alumina in the manufacture of the metal, and the tedious and costly chemical refining process is thereby avoided. A previous refining treatment of the bauxite is in all cases necessary, to remove the impurities (iron and silica), which otherwise would so contaminate the resulting metal as to render it practically worthless.—Ed.]

BALDWIN LOCOMOTIVES.

For the six months ending June 30th, the Baldwin Locomotive Works, Philadelphia, Pa., turned out 1,000 locomotives, an increase over the corresponding period of last year of 306 locomotives, or 44 per cent. This is the largest number of locomotives ever turned out by the plant. If the locomotive company had greater facilities they could still further increase their output. Each day since January the company averaged the construction of five and sixteen-thirtieths locomotives. The greatest number was turned out in April and the least in February. The following table shows the number constructed each month, as compared with the same time in 1902:

	1902.	1903.
January	87	142
February	102	132
March	124	170
April	128	191
May	127	185
June	116	184
	694	1,000

COMMERCIAL APPLICATIONS OF LIQUID AIR.

Liquid air is delivered in Berlin, 2 liters (0.528 gallons) at a time, for about twenty-five cents. In a recent issue of *Energie*, of that city, it is stated that the receptacles are made of glass, with double walls, the space between the walls being filled with an insulating material, the walls being silvered to prevent the radiation of heat and the whole enveloped in an insulating material. They retain their temperature for fourteen days. Several drops of the liquid in a glass of water produce freezing, and it is intended for such uses as refreshing drinks and improving the condition of the air in sick rooms.

ACETYLENE BLOWPIPE.

The adaptation of the blowpipe to the use of acetylene gas is an accomplished fact, and an interesting article by Andre Binét in *Le Genie Civil* sets forth its many advantages over other types of the instrument mentioned. Of these not the least is the very high temperatures which can be obtained; this last is not absolutely known, but is in the neighborhood of 4,000°, and in any event much higher than the oxyhydrogen blowpipe is capable of. Oxygen is used in connection with acetylene, and being of higher calorific power than hydrogen accounts for the increase of temperature; the lower cost of acetylene as compared with that of hydrogen is also important where the blowpipe is to be used for any length of time. The flame can be easily regulated as to its power, for the brilliant illumination given by acetylene renders the effect of the different quantities of oxygen immediately visible, the reverse being the case where hydrogen is employed. Tests made with the new process show welded steel bars to have a tensile strength of 49,770 pounds per square inch.—*Iron Age*.

Book Notices.

Traité Theoretique et Practique des Moteurs a Gaz et a Petrole. Par Aimé Witz, Ingénieur des Arts et Manufactures, Docteur ès Sciences, etc., etc.; 4^e edition, refondue et entièrement remaniée. Tome 1 (4to, pp. vii + 504). Paris: E. Bernard, Imprimeur-Editeur. 1903.

This elaborate treatise on gas and oil engines has grown from a small duodecimo volume of 288 pages, first issued in 1886, to the imposing quarto, of which the first volume is above designated. The author is a voluminous writer on the subject and the present volume may be regarded as his *chef d'œuvre.* It treats of the history and classification of motors, the gas of cities and carburetted air, lean gas, the gas of blast furnaces, acetylene, petroleum, gasolene and alcohol; of the theory of gas motors, methods of calculating their power, and the results of tests of their efficiency. This volume is well printed and finely illustrated. W.

Grundriss der reinen und angewandten Elektrochemie. Von P. Ferchland, Dr. phil. Mit 59 Figuren im Text. (8vo, pp. vii + 271). Halle a. S.: Wilhelm Knapp. (Price, 5 marks.)

This work appears to be a thorough treatise on the principles of electrochemistry. It discusses the subject under three heads. After a brief historical introduction, the first part is devoted to the consideration of electrolytic conduction, in which are treated the fundamental concepts, Faraday's laws resistance and conductivity, the theories of Grotthus, Clausius and Arrhenius; the relations between the theory of electrolytic dissociation and the modern theory of solutions, etc., etc.

The second part discusses the energy modifications in electrolytic processes, under which are treated the calculations and measurement of E.M.F.s E.M.F.s and the mechanical theory of heat, the osmotic theory of Nernst, polarization, etc.

The third part treats of Special and Applied Electrochemistry, embracing electrothermic processes, technical electrolysis, secondary batteries, etc.

The mechanical make-up of the book is excellent. W.

Electric and Magnetic Circuits. By Ellis H. Crapper, M.I.E.E., Head of the Electrical Department, University College, Sheffield. (8vo, pp. v + 379.) London: Edward Arnold. New York: Longmans, Green & Co. 1903.

This book is described as being the introductory volume of a treatise on electrical engineering. It deals with the fundamental principles of electricity and magnetism and seeks to explain all the essential relationships of electric and magnetic circuits met with in continuous current working.

The subject is treated under the following heads, viz.: Practical Electric Units, Electric Circuits and Electric Effects, Principles of Distribution and Design of Mains, Magnetism, The Magnetic Circuit, Coil-Winding Design, The Generation of Electric Pressures, Types of Dynamos, The Electric Motor, Efficiencies and Dynamo Calculations, Systems of Electrical Units, Useful Tables and Constants.

The author has endeavored to meet the wants of students of electrical engineering by the introduction of numerous—nearly 700—exercises. W.

Chemistry, Inorganic and Organic, with Experiments. By Chas. Loudon Bloxam. Ninth edition, rewritten and revised. By John Millar Thompson, LL.D., F.R.S., Professor of Chemistry, King's College, London, and Arthur G. Bloxam, F.I.C., Consulting Chemist, etc. Large 8vo, pp. xi + 872. Philadelphia: P. Blakiston's Son & Co. 1903. Price, $6.00, net.

The abovenamed work is a new edition of a longtime standard text-book revised and brought up to date. A number of changes have been introduced in the treatment of the subject to conform to modern views, but the general characteristics that have made the work so popular have been retained. This is especially noticeable in the constant reference to experiments to illustrate the subject. W.

Engineering Preliminaries for an Interurban Electric Railway. By Ernst Gonzenbach. (8vo, pp. 71). New York: McGraw Publishing Company. 1903.

This work gives a careful exposition of the technical details needful for the engineer or exploiter of such enterprises, for the construction of an interurban electric railway. The problem has been apparently thoroughly studied and worked out on very conservative lines, and the work should prove extremely useful for its intended purpose. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, September 16, 1903.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 16, 1903.

Vice-President WASHINGTON JONES in the chair.

Present, 19 members and visitors.

Additions to membership since last report, 32.

Mr. Frank C. Watson, Assistant Superintendent of Bridges, Bureau of Highways, Philadelphia, exhibited and described a series of photographic views of a large number of the bridges maintained by the municipality. The structures shown and described were chiefly the minor bridges.

The speaker was given a vote of thanks at the close of his remarks.

Adjourned,
WM. H. WAHL,
Secretary

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CHEMICAL SECTION.

Stated Meeting, held Thursday, April 30, 1903.

Radio-Activity.

BY EDWARD A. PARTRIDGE and ROBERT H. BRADBURY.

I. HISTORICAL.

The history of science presents us with frequent illustrations of the fact that an erroneous hypothesis may be extremely helpful to the progress of knowledge. If an hypothesis is incorrect, investigation will reveal the error and the facts which are gathered in the course of the work will remain as a permanent heritage.

Radio-activity is a case in point. The investigations in this direction started from the idea that the Röntgen rays were due to the phosphorescence of the inner walls of the vacuum tube. It occurred to Becquerel that if this were true, then all phosphorescent substances should produce Röntgen rays when excited by light. To test this he wrapped a photographic plate in black paper, laid upon it a crystal of uranyl potassium sulphate—a highly phosphorescent substance—and exposed the whole to sunlight. The plate was acted upon as he expected, but additional experiments revealed the surprising fact that an excitation of the uranium salt was unnecessary—the whole process occurred equally well in the dark. Further, it was found that uranium itself—which is not phosphorescent—exerted a more vigorous action on the plate than potassium uranyl sulphate.

At once it became necessary to drop the idea of rays excited by the action of light upon phosphorescent substances and to substitute the conception of uranium itself as a source of inexplicable radiations. All uranium compounds were found to be active, and there appeared to be a direct relation between the degree of activity and the uranium content.

At this stage (1898) P. and S. Curie began their remarkable work on the subject with a quantitative investigation of the radio-activity of a vast number of substances. Obviously the photographic method is unsuitable for quantitative work and can only give, at the best, rough approximations. Fortunately there is another effect of the Becquerel rays which can readily be measured—they confer upon air the power to conduct the electric current. If, then, two condenser plates are brought to a constant difference of potential and a radio-active substance is brought between them, a current will pass which can be measured. Other things being equal, the strength of this current will be proportional[1] to the radio-activity of the substance. For rough work a charged electroscope is sufficient. The approach of a radio-active substance discharges it, and if the leaves are always brought to the same angle of divergence and the radio-active preparation held at the same distance, the time of discharge is an inverse measure of radio-activity.

Two of the results of this work of the Curies are especially important. First, compounds and minerals containing uranium and thorium are radio-active—in the absence of one of these elements radio-activity is not noticed. Second, some minerals containing uranium are far more active than uranium itself. Thus, chalcolite is about twice as active and some samples of pitchblende four times as active as metallic uranium.

Clearly it could no longer be held that the production of Becquerel rays is a property of the uranium atom, for in that case uranium would be the most active of all substances. Thus emerged the idea of elements of great radio-active energy accompanying uranium in its compounds. Varying radio-activity is easily accounted for by the supposition of a larger or smaller content of the real radio-active element. Guided by this thought, the Curies worked up large quantities of pitchblende by the ordinary analytical process, carefully testing each precipitate for radio-activity. The difficulty of the task was great, for pitchblende has an exceedingly complex composition, containing nearly all the known elements. The quantity of real radio-active substance in it is very small, probably one part in a million, so that it is necessary to work it up by the ton.

They were encouraged at the start by the observation that when the mineral is heated the sublimate obtained is much more active than the pitchblende itself.

II. PREPARATION AND PROPERTIES OF POLONIUM AND RADIUM.

In the course of this work the Curies found that the *bismuth* separated from the pitchblende was about 100 times as active as uranium. This led them to assume the presence in it of small quantities of a new radio-active element to which they gave the name of *polonium*. By various methods they were able to fractionate the precipitate and to increase its strength. But in all cases the radio-activity of the Curies' polonium preparations rapidly diminished with time and finally disappeared almost completely. This points to the conclusion that the Curies' polonium is simply bismuth which has been made secondarily radio-active by contact with the *radium* of the pitchblende.

Marckwald* has separated from the bismuth of pitchblende a radio-active substance which behaves in a very different way. He dissolved the active bismuth precipitate and subjected it to fractional electrolysis. The small quantity of black substance first precipitated was intensely active. It appeared therefore that the radio-active element was a "nobler" metal—*i. e.*, had a smaller solution pressure—than bismuth itself. This led him to try the effect of placing a rod of bismuth in the solution. This was covered with a black coating and acquired an activity equal to that of the best radium preparations. The rays differ from those of radium in their complete lack of penetrating power. Wrapping the rod in filter-paper is sufficient to stop the radiation completely. This explains the fact that an increase in the thickness of the coating does not increase the strength of the radiation. The coating on one of Marckwald's rods weighed, when scraped off, only 5 milligrams. When it was heated a small quantity vaporized and the rest melted to a silvery globule which was extremely brittle. Since in the absence of concentration-differences in the solution a metal cannot precipitate itself, the new substance cannot be bismuth. Of late Marckwald has concluded that it exhibits the closest chemical similarity with tellurium, and proposes for it the provisional name *radio-active tellurium*. It is important to notice that the radiation of Marckwald's substance does not decrease with lapse of time. Bismuth rods coated in the way indicated are to be brought into commerce. They can be used for the purpose of distinguishing genuine diamonds, which phosphoresce on their approach, while imitation gems do not.

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* Berichte der deutschen chem. Gesellschaft, 35, p. 2285 ; 35, p. 4239.

Let us now return to the work of the Curies. In the systematic separation of pitchblende they made the important observation that the *barium* obtained was strongly radioactive. The name *radium* has been given to the active element associated with the barium. In order to separate the two, various methods of fractionation must be resorted to. Thus radium chloride is less soluble in water and in very dilute hydrochloric acid. Giesel * finds that it is better to work with the bromides, since the solubility differences are greater. Radium has a higher atomic weight than barium, and Madame Curie followed the course of the fractionation by determining the atomic weight, which steadily increased with the intensity of the radiation. In the following table the radio-activity is measured in terms of that of uranium as unity.

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* Radio-active Substanzen und deren Strahlen. Ahrens' collection, vol. 7, p. 1. This article has furnished many facts for the present summary.

Radio-activity.	Atomic Weight.
60	138
3000	140
4700	140.9
7500	145.9
very great	175

She has obtained an atomic weight of 225 on a still purer preparation.

Giesel* kept track of the fractionation by means of the flame-color of radium, which is pure carmine.

The existence of radium is to be regarded as well established. The spectrum has been carefully examined by Demarçay, Giesel and Runge. Madame Curie has obtained practically pure $RaCl_2$ and Giesel, has obtained $RaBr_2$ in pure condition.

Radium bromide when kept in the air gives off bromine and acquires an alkaline reaction which is due to the formation of radium hydroxide. This absorbs CO_2 and passes into the carbonate. $RaBr_2$ is soluble in water, and the solution soon becomes yellow from the liberation of bromine. The crystals appear to contain an occluded gas—at least a gas escapes with effervescence when they are dissolved. A slow and apparently unlimited escape of gas takes place from the solution. The presence of a halogen somewhat complicates matters, but with non-halogen compounds the phenomenon is as simple as it is astounding. *The gas which is continuously liberated is a mixture of hydrogen and oxygen in the relation 2 : 1 by volume.*† There occurs, therefore, a kind of continuous electrolysis of the solution, but without any current or other assignable source of energy. The change is not a chemical reaction between the radium compound and the water, for already a quantity of hydrogen has escaped from Bodländer's solution, which corresponds to 10 atoms for every atom of radium it contains, and there are no signs of an end of the evolution. This simultaneous and separate escape of hydrogen and oxygen from the bosom of the same liquid gives a severe shock to certain old, cherished and well-grounded views about the activity of elements in the nascent state. Platinum, which exhibits a pretty general catalytic acceleration of reactions in which gases are formed and escape, retards this one since it brings about the reunion of the separated hydrogen and oxygen. Radium carbonate—an insoluble salt—produces a similar decomposition of water in which it is suspended. It has been remarked that a solution of radium bromide rapidly becomes yellow from separated bromine. The gas which is evolved from the liquid is a mixture of detonating gas with an excess of hydrogen equivalent to the bromine which has passed from the ionic to the molecular condition. This gas is itself radio-active, excites sensitive substances to phosphorescence and blackens the glass pipettes in which it is collected.

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* Berichte, 35, p. 3608 (1902).

† Bodländer. *Chemische Zeitschrift*, 2, p. 396 (1903).

Radium compounds are luminous in the dark. One preparation containing radium and barium chlorides gave a light so bright that it was possible to read by it. The phosphorescence of pure radium compounds is bluish and intense, but soon fades. On the other hand, the impure preparations containing much barium retain their luminosity unchanged for years. When a radium preparation is brought near the closed eye there is a sensation of light which is probably due to the phosphorescence of the interior of the eye under the influence of the rays.

CHEMICAL AND PHYSIOLOGICAL EFFECTS OF BECQUEREL RAYS.

In Berthelot's * experiments on this subject the radium preparation was inclosed in a single or double-sealed tube so as to exclude the possibility of chemical action between it and the substance whose behavior was being investigated. Iodine pentoxide separated into iodine and oxygen. Nitric acid was colored yellow probably by a change of a similar

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* *Compt. Rend.*, 133, p. 659.

character to its decomposition by light. However, in other cases the effects of the rays differed from those of light. Thus a solution of sulphur in carbon disulphide, which separates insoluble sulphur under the influence of light, remained unchanged by radium rays. Oxalic acid and acetylene, both of which are affected by light, were not acted upon. White phosphorus passes into red phosphorus under the influence of Becquerel rays. Oxygen is converted into ozone. Glass is colored brown or violet. Berthelot—who used a lead glass—considers that the change is due to the separation of metallic lead in the glass. Compounds of potassium and sodium are colored bluish-green or violet, the action being similar to that of Röntgen rays on the same substances except that it penetrates into the interior in place of being confined to the surface. The color fades when the substance is placed in the light. Elster and Geitel and Giesel believe that the colors are due to the separation of a small quantity of metal which forms a solid solution in the salt, and Giesel has produced similar effects by treating the haloid salts with the vapor of potassium or sodium. Paper becomes brown and brittle under Becquerel radiation and celluloid loses its solidity.

Many of the chemical effects just mentioned are endothermic and require a continuous supply of energy in order to bring the change about.

Inflammations on the fingers are a frequent sequence of work with radium preparations. Giesel placed a celluloid capsule containing a small quantity of a radium preparation against the skin of the arm for two hours. The result was a gradual but vigorous inflammation, followed by blistering and loss of the epidermis. Healing followed, but the growth of hair has not been renewed. The green parts of plants lose their chlorophyll under Becquerel radiation and turn brown or yellow. Seeds lose the power of germination.

The principal physical properties of the emanations from radio-active bodies are the following:

They render insulators temporarily conducting. A charged electroscope surrounded by air or paraffin is discharged in their presence.

Some of the rays are deflected by a magnetic field while others are not.

Solids are more or less transparent to them.

Many substances, such as barium platino-cyanide, fluoresce under the influence of the rays.

Radio-active substances continuously emit light and heat.

Some of the invisible rays are reflected according to the law for light.

According to Rutherford,* radium emits three kinds of rays which he denominates α, β and γ.

(1) The α-rays are readily stopped by thin layers of matter, even by tissue-paper, and produce the greatest part of the ionization of gases observed in ordinary experiments. They consist of, positively charged particles.

(2) The β-rays consist of negatively charged particles and are similar in all respects to kathode rays. a and β-rays are deviated by a magnetic field.

(3) The γ-rays are not deviated by a magnetic field and are capable of great penetration.

The difference in penetrating power of the three classes of rays is shown by the following table, which gives the thickness of aluminium that reduces the intensity to one-half its original value:

a-rays,	·0005	centimeters.
β-rays,	·05	"
γ-rays,	8·	"

The amount of energy given off by radium compounds as α-rays is about 1,000 times as great as that radiated as β-rays.

It has been established that the residual activity of uranium and thorium freed from uranium-x and thorium x consists entirely of α-rays. The radiation from uranium-x consists almost entirely of β-rays, while thorium-x sends out both a and β-rays. It appears, therefore, that the emission of a-rays is independent of the β-rays.

A thin-walled tube containing a radio-active substance should show a diminution of weight in consequence of the continuous loss of changed particles. Heydweiller has shown that this is apparently the case. The loss of weight is, however, extremely small with the quantities he used, about ·0005 gram in four weeks. Rutherford points out that this may be due to the influence of the radiation upon the surface of the glass tube.

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* *Phys. Zeil.*, 1903, p. 235

Curie and Laborde[*] have quantitatively examined the heat emitted by radium. One gram of radium gives off heat the amount of which is of the order of 100 gram calories per hour. One gram-atom of radium gives off per hour an amount of heat comparable with the heat produced by the combustion of a gram atom of hydrogen.

The measurements were made with a thermo-electric couple of iron and constantan, one junction of which was surrounded by radio-active $BaCl_2$ and the other by pure $BaCl_2$. The observations were confirmed by the Bunsen calorimeter.

Lodge[†] remarks that the development of heat is probably connected with the emission of the positively charged particles. He calculates that the emission of 1,000,000 charged atoms per second, with a velocity one-tenth that of light, would represent an amount of energy equal to 1,000 ergs per second, which would correspond to heat enough to melt 1 milligram of ice per hour. The loss of matter would amount to $\frac{1}{20}$ of a milligram in a century.

The position of radium in the periodic system is the subject of a recent paper by Runge and Precht.[‡]

As is well known, the spectra of related elements are definitely analogous. Runge and Precht found that the strongest lines of radium are exactly comparable to the strongest lines of barium and to the corresponding lines of magnesium, calcium and strontium. Moreover, the lines in these spectra occur in pairs, and the distances between the lines of the corresponding pairs are related to the atomic weights of the elements to which they belong. The law is as follows: In every group of chemically related elements the atomic weights are proportional to some power of the distance between the lines of corresponding pairs. Usually the exponent of the power is not a whole number. This law can be transformed thus: "If the logarithms of the atomic weights and distance between lines of pairs be taken as co-ordinates the corresponding points of a group of chemically related elements will lie on a straight line."

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[*] *Electrician*, 1903, p. 970.

[†] *Nature*, 1903, p. 511.

[‡] Runge and Precht: *Astrophysical Jour.*, 1903, p. 233.

This law is illustrated by *Fig. 1*, which is from Runge and Precht's paper. We see from this figure that, among the alkali metals, potassium is the only one that falls below the straight line through the remaining points. It is interesting to note that the law shows a comparatively large deviation for potassium, since its atomic weight should be greater than that of argon to fit into the periodic system.

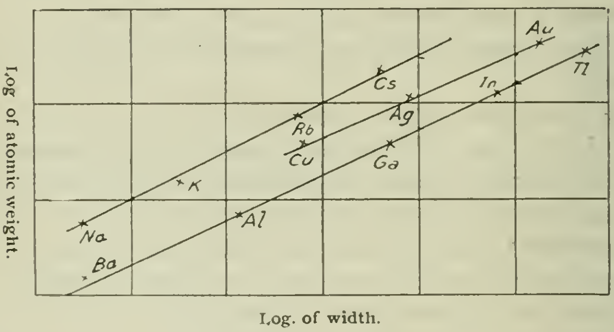

FIG. 1.

Fig. 2 shows the application of the law to the alkaline earth metals. Extrapolation gives 258 for the atomic weight of radium as opposed to 225, the value determined by Madame Curie. This would naturally be anticipated, since any impurity would lower the atomic weight, and it is very difficult to separate radium from barium. F. Rinne has found that the bromides of the two elements are isomorphous, so that it is probable that they would crystallize together in an isomorphous mixture. The number 225 fits the periodic system better in that it fills the gap between bismuth and thorium in the correct column.

For the atomic weight 258, radium would be displaced two rows farther in the column *Mg*, *Ca*, *Sr*, *Ba*, and a number of new unoccupied places would arise. The point remarked by Rutherford may be cited in support of the higher atomic weight. The greater the mass of the atom the more complicated is its probable structure, and electrons would be thrown off with greater ease.

Source of Energy.—Concerning the source of energy emitted by radio-active substances, we are absolutely in the dark. All that can be done is to mention some of the many hypotheses that have been offered to explain the phenomena.

(1) That the energy is chemical in character and is given off in consequence of a continuous modification of the *Ra* atom. The enormous amount given out renders this supposition highly improbable. Demarçay has advanced the argument, against this idea, that the spectrum of *Ra* shows no modification at the end of five months. Demarçay's notion does not seem valid, since to produce a spectrum energy is added in large amounts.

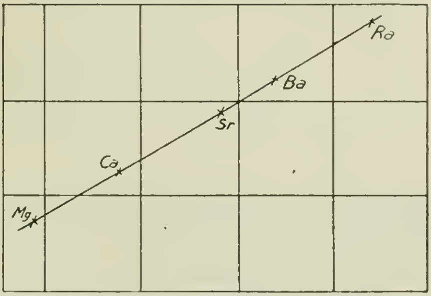

FIG. 2.

(2) That radio-active materials absorb energy of ether disturbances that do not noticeably affect ordinary substances.

(3) That atoms of *Ra* and similar substances act selectively upon the moving molecules of the surrounding gas after the manner of Maxwell's demons. (Crookes.)

(4) That radio-active substances absorb gravitational energy. To prove this some radium compound in a dish

was placed under one pan of a balance. That pan was apparently lighter than usual; the loss of weight gradually decreased. A second experimenter, however, observed that placing an empty dish under a balance pan causes apparent loss of weight, the necessary condition for the success of the experiment being that the dish must be touched with the fingers. Ascending currents of warm air completely account for the phenomenon. Repetition of the original experiment by Froch,* using great precautions, has shown that no loss of weight and hence no absorption of gravitational energy takes place.

Induced Radio-activity.—Substances that have been exposed to the emanations of radio-active bodies become themselves temporarily active. The law of the decrease of induced radio-activity has been carefully studied by Curie.† When a body made active by remaining in an enclosed space with a radium compound is brought into free air it loses its power to emit rays according to an exponential law. It loses one-half its activity in half an hour.

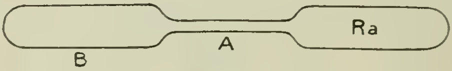

FIG. 3.

Radium or a radium compound is placed in a tube of the form shown in *Fig. 3*. If after a time it is sealed off at *A* the portion *B* shows radio-activity, which decreases according to an exponential law, falling to one-half in four days. If *B* is opened and the enclosed air allowed to diffuse with the air of the room, the decrease of activity follows the rapid exponential law, that is, it falls to one-half in half an hour. If the tube was vacuous before sealing the rapid law was followed; this was also the case if air was admitted after sealing. The emanation apparently comes from the walls of the glass vessel, since immediately after removing the air the intensity is unaltered.

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* *Phys. Zeit.*, 1903, 318.

† *Phys. Zeit.*, 1903, p. 314.

The algebraic form of the law which the fall of intensity follows is:

$$I = I_0 \, e^{-\frac{t}{\theta}}$$

I = intensity at time t.
I_0 = initial intensity.
t = time since first observation.
θ = a constant time = 5·752 days.

Some observations were continued for twenty days, I had then fallen to $\frac{1}{27}$ its initial value.

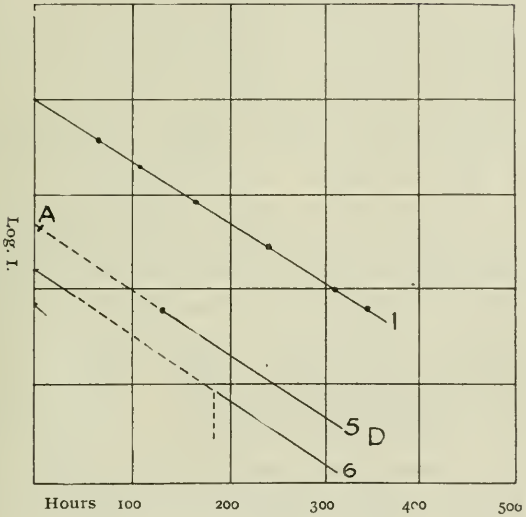

FIG. 4.

I falls to one-half its initial value in three days, twenty-three hours and forty-two minutes.

The constant θ remains the same under widely differing conditions. The following are some of the modifications of the experiment; in all cases θ was found to be the same:

(1) Radium solutions of very different activities were used.

(2) Solid Ra Cl_2.

(3) Form and dimensions of tube varied from 3 centimeters to 2,000 centimeters.

(4) Thickness of glass walls changed.

(5) Copper and aluminum vessels used in place of glass.

(6) Induction took place through tubes long and capillary, or short and wide.

(7) Time of induction varied between fifteen minutes and one month.

(8) Pressures varied from 1 atmosphere to 2 centimeters of mercury.

(9) Hydrogen or carbon dioxide used instead of air.

The same law is observed whether the external emanation or the internal conductivity of the tube is measured. Temperature has no influence upon the rate of loss of induced radio-activity. After some measurements were made with some tubes, they were maintained at a temperature of 450° for three days, then brought to normal temperature; the intensities of the radiations were the same as if they had been continually at the normal temperature. Other tubes were kept in liquid air for six days, at the end of which time they showed an activity abnormally low. After they had remained at the ordinary temperature for half an hour the intensity had risen to what it would have been if they had never been cooled. These facts are illustrated in *Fig. 4*, in which abscissæ are times in hours and ordinates are logarithms of intensities. Line 1 shows the decrease of intensity at ordinary temperature. Line 5 illustrates the experiments in which the tubes were heated to 450°, the dotted portion relating to the time during which the heating took place. Line 6 refers to investigation of the effect of refrigeration; the dotted line here shows time during which the tubes were cooled.

CENTRAL MANUAL TRAINING SCHOOL,
Philadelphia, April, 1903.

A GOOD ENGINE RECORD.

A straight line engine, in use at the works of the Solvay Process Company, in Syracuse, N. Y., recently completed a continuous run of 22 months, during which period it had not once been stopped. Its speed was 250 revolutions per minute, which makes 15,000 per hour, 360,000 per day, nearly 11,000,000 per month, and a grand total for the 22 months of some 241,000,000 revolutions without a stop. This speaks well for the excellence of the design and workmanship expended upon the engine, and for the excellence of the attendance received.—*Iron Age.*

PHYSICAL SECTION.

Stated Meeting, held Thursday, October 1, 1903.

Airy's Theory of the Rainbow.

By D. Hammer.

Up to some seventy years ago Descartes' view of the formation of the rainbow was universally accepted. In 1836 the English astronomer Airy published a new theory, but, as it often happens, it found few admirers, some admitting it only for the explanation of the so-called supernumerary bows. Of late years, however, several scholars have endeavored again to draw the attention of scientists to Airy's theory; as prominent among them may be mentioned Messrs. Mascart and Pernter.

Why, then, one might ask, is Airy's theory so little known whilst that of Descartes is almost universally taught? The reason may be found in the difficult calculations requisite for a full understanding of Airy's theory. If, therefore, it cannot, to a sufficient degree at least, be brought within the reach of non-experts in physics and higher mathematics, no one will require of our colleges and text-books to pay much attention to it. But this is not the case. In his "Ein Versuch, der richtigen Theorie des Regenbogens Eingang in die Mittelschulen zu verschaffen," Mr. Pernter succeeded in putting it into such form that it may without difficulty be introduced into high-schools and colleges.

In this essay we shall strive for the same end; our material is drawn from Mr. Pernter's writings on this subject.*

In order to show the differences between the two theories, we first give a short account of that of Descartes.

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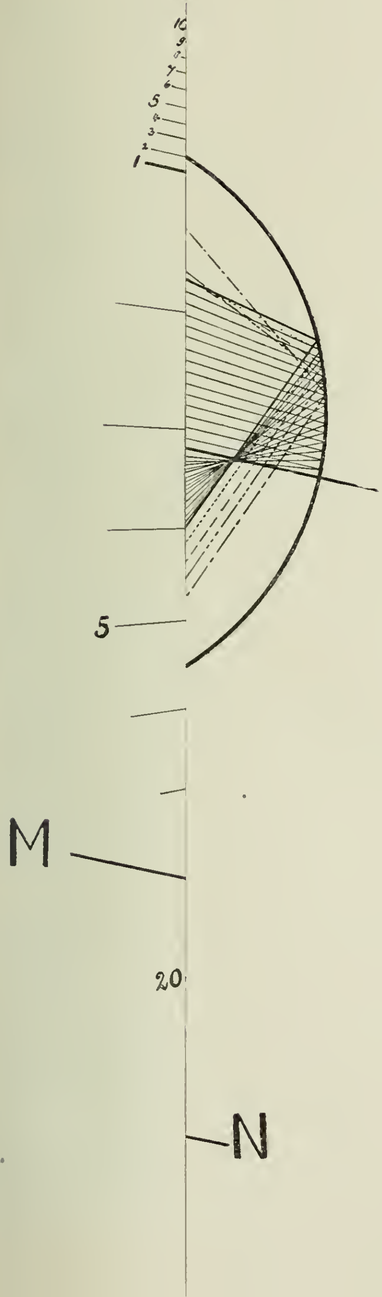
* "Ein Versuch, der richtigen Theorie des Regenbogens Eingang in die Mittelschulen zu verschaffen," "Neues über den Regenbogen" and "Die Farben des Regenbogens."

Dr. J. M. Pernter is Professor at the University of Vienna (Austria); he is acknowledged as an authority in meteorology.

Fig. 1 represents the formation of the principal rainbow. A bundle of parallel rays strikes the raindrop. The one, which passes through the centre of the sphere, is not deviated from its course, but all the others undergo a change in their former direction, corresponding to the respective angles of incidence. Following up one of them we see that after two refractions and one reflection it makes a certain angle with the line MN, the axis of the rainbow. This angle we call O. If now we take different angles of incidence increasing at a constant rate from 1° to 90°, we find by construction as well as by calculation, that the angle O varies unequally, growing larger and larger, till, at an angle of incidence of about $59° 24'$ having reached its maximum, it again retrogrades to 0. Near this limit O has its smallest rate of variation; hence much more light will be accumulated on this spot than at any other place of the illuminated field. It is this crowding together of (say) red rays that enables us to see the red of the rainbow. Now since every color has its own index of refraction every color has also its own maximum O. From this consideration it naturally follows that we must always see the well-known seven colors of the rainbow and that, provided the apparent diameter of the sun be the same, the width of the bow and its colors remain unchanged. The reason is, the index of refraction, on which the calculation depends, is a constant quantity, and the size of the raindrop, the only variable, is disregarded entirely. Hence the characteristic mark of Descartes' theory is constancy. It is simple in itself and easily understood, but facts prove its insufficiency.

To convince the reader of this assertion, we are to give an accurate description of the rainbow, a task which, though at first sight may seem superfluous, is of real necessity, if we wish to correct several misconceptions. "Want of accuracy in observing the phenomenon," says Mr. Pernter, "contributed perhaps more than anything else to the fact that many were satisfied with an inadequate explanation, thus keeping up until the present day a properly false theory which otherwise would have been dropped."

Here we need not dwell upon such particulars as the axis


M
N

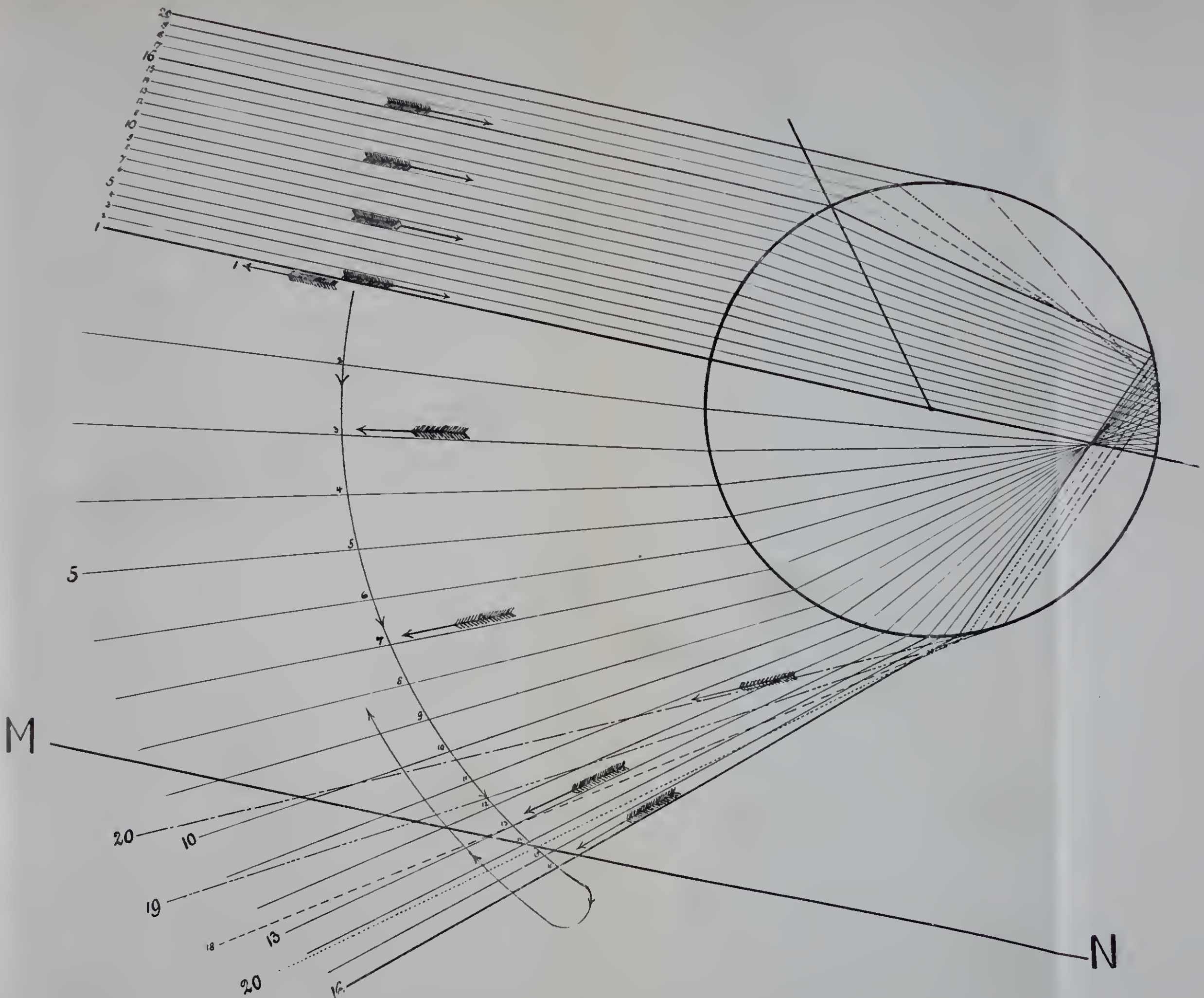


FIG. 1.—Illustrating Descartes' theory.

of the rainbow, the concentricity of the arches, their division into principal and supernumerary bows (in the sequel we will designate the former as first, second, third, etc., rainbows; the so-called supernumerary bows we comprise under the name of "secondary" bows). All this supposed as known, we briefly enumerate those features which are sometimes overlooked, although just they furnish a strong proof that Descartes' theory is far from being complete enough to give a sufficient explanation of the phenomenon.

(1) In the principal rainbows the colors are neither always the same nor is their distribution constant. Most frequently no blue is seen, in other cases a really pure red is wanting; dark blue occurs rather as an exception. Now, yellow almost disappears, whilst green and violet are prominent; again, yellow and green occupy the greater part, violet being reduced to a narrow extension. The intensity also changes: frequently the brightest spot lies in the beginning of violet. Finally, the variations in the width of both, arch and its colors, cannot escape the eye of any attentive observer.

(2) The secondary bows are characteristic of the rainbow, so much so that they are by no means a rare occurrence and their absence is rather the exception. They often lie hard against the violet of the first rainbow and extend inwards; under exceptionally favorable circumstances they border upon the violet of the second bow and extend outwards. They, too, in accordance with the entire phenomenon, undergo several changes: their number varies from six to one, sometimes they are wanting altogether; mostly made up of green and rose, they now and then show yellow, green and purple or yellow, green, blue and rose.

To the white rainbow we shall afterwards devote special attention on account of its importance for the new theory.

After this description of the rainbow, it is understood that that theory deserves our preference which accounts for all the numerous variations and explains the phenomenon in harmony with both light-theory and experiments. Airy's theory may justly claim this prerogative. According to it the rainbow is essentially a phenomenon of diffraction; this statement, as we are going to show, derives its proofs from theory as well as experiments.

Fig. 2 is constructed for rays whose index of refraction (n) equals $\frac{4}{3}$ (red-orange near the Frauenhofer's line C). As is seen, the rays which after refractions and reflection are prolonged backwards, form each a certain angle with AS, the ray that passes through the centre of the sphere. This angle we call D. Its formula for all possible rainbows is:

$$D = k\pi + 2[i - (k + 1)r],$$

k standing for the number of reflections, i for the angle of incidence and r for that of refraction. Putting in p for $k + 1$, we have

$$D = k\pi + 2(i - pr).$$

Examining the figure more closely we find that the heavy line occupies a peculiar position; for the angle it makes with AS is a minimum. This angle, which we may denote by Dm, is to be found by means of the formulas:

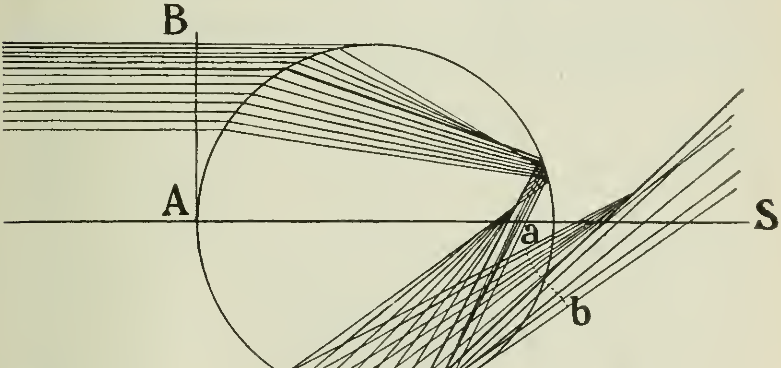
$$\sin I = \sqrt{\frac{p^2 - n^2}{p^2 - 1}} \text{ and } \cos I = \sqrt{\frac{n^2 - 1}{p^2 - 1}},$$

I standing for the angle of incidence corresponding to Dm.

In the subjoined table Dm is worked out for the five first rainbows:

For Water.			For Glass.		
k.	I.	Dm.	k.	I.	Dm.
1	59° 24′	$\pi - 42°\ 4'$	1	49° 48′	$\pi - 22°\ 51'$
2	71° 49′	$\pi + 50°\ 56'$	2	66° 43′	$\pi + 86°\ 52'$
3	76° 50′	$2\pi - 42°\ 48'$	3	73° 13′	$2\pi + 9°\ 8'$
4	79° 38′	$2\pi + 43°\ 46'$	4	76° 48′	$3\pi - 71°\ 6'$
5	81° 20′	$3\pi - 51°\ 42'$	5	79° 6′	$3\pi + 27°\ 29'$

What then is the relation of the least-deviated ray to the formation of the rainbow? *Fig. 2* shows it. All the rays, which come from a single point of the sun's surface and strike the drop, are practically parallel, owing to the great distance of the sun. Hence the wave-front can be designated by the line *AB*, perpendicular to one of them. But when the same rays leave the drop, their wave-surface has necessarily become curved as shown in the figure by ***ab.*** The curvature is such that the least-deviated ray forms its turning point. But somewhat divergent rays cannot be united into one image in our eyes, hence, in case the rainbow is perceived, it can only be ascribed to rays that deviate least from parallelism: such are those in the nearest vicinity of the least-deviated ray. The very small portion of the wave, the rays of which are effective, is represented in *Fig. 2a*, being, of course, highly magnified.



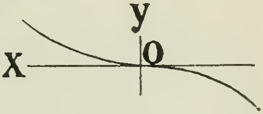


FIG. 2a.

FIG. 2.—Illustrating Airy's theory.

The mere shape of this wave-front may tell us that we have to deal with the phenomenon of diffraction. This statement is based on Huyghen's principle, which says that the effect of a wave surface must be considered as the sum total of the effects of each point in the surface, whereby each point is taken as a wave-former of its own, *i. e*, it sends out rays in all directions. In case of spherical wave-fronts the final result is the same as if the wave had been produced only in the centre of the sphere. But this is not true for other curved waves, particularly if there is question of curvatures having a turning point. In this case diffraction must take place. If we use monochromatic light, an alternate series of light and dark bands will be observed; with white light these bands show a most beautiful variation of hues. Hence the phenomenon is analogous to that observed through a diffraction-grating; still it offers a somewhat different character, since the producing wave-surface is of a peculiar shape.

We now come to a point which Descartes' theory does not at all take into account, namely, the fact that the ever varying distribution of colors and consequently the rainbow itself necessarily depend on the size of the drops.

The efficiency of the rays (*Fig. 2a*) depends on the equation of the wave-front. Calculation has established it to be

$$y = Hx^3,$$

wherein

$$H = \frac{h}{3a^2},$$

a standing for the radius of the drop and h for

$$\frac{(p^2 - 1)^2}{p^2(n^2 - 1)} \sqrt{\frac{p^2 - n^2}{n^2 - 1}}.$$

From this equation it follows that such a wave-surface necessarily gives rise to diffraction; moreover, since the radius of the drop enters as a factor into the equation, the further conclusion must be, that with differently sized drops the phenomenon will show a different character. Given the equation and the radius of the drop we are enabled beforehand to construct the rainbow that will result. Mr. Pernter undertook this weary task and in an essay on the colors of the rainbow published the results obtained for drops whose radius respectively is: 1,000, 500, 250, 150, 100, 50, 40, 30, 25, 20, 15, 10, 5 μ ($\mu = \frac{1}{1000}$ millimeters.)

The following four diagrams we present to the reader remarking that they are not the result of mere speculation, but that, partly at least, they were proved correct by actual experiments.

We must now prove that these theoretical conclusions are borne out by experiments, which, in order to show the principal features of the phenomenon, may be performed without great difficulty.

A few remarks must be made regarding the mode of procedure.

Since the right section of a cylinder is a circle as well as the section of a sphere, we may in carrying out the experiment make use of cylinders or of spheres indifferently; the only difference will be that with cylinders we shall obtain a straight band and with spheres a real bow, a circumstance of little importance. It is obvious, moreover, that essentially the same phenomenon will be obtained in case the light falls upon glass instead of water; the angles under which we have to view the bow will correspond to the index of refraction proper to glass. The latter method affords the advantage that it brings out the image distinct, sharp and richly colored, which is not the case when we use cylinders or spheres filled with water. It is self-understood that for making very accurate researches it would be necessary to employ nothing but water, a rather difficult task. But for the purpose of proving the correctness of Airy's theory, cylinders, spheres or even threads of glass will suffice, the only condition being that they are well formed and without impurities.

In the experiments we proceed as follows:

We use a spectrometer the telescope of which combines a large field of view with a moderate magnifying power. In the centre of the apparatus we attach a glass cylinder from 2 to 3 millimeters in diameter and put a red glass in front of the slit. Then through a porte-lumière we allow a beam of sunlight to pass to the cylinder. Since in the first bow (see table above) the light is deviated from its original direction by an angle of $\pi - 22° 51'$, the telescope must be turned accordingly. In this position we see a long series of red bands growing less in intensity and width. Next we put in, instead of the red glass, a blue one: only blue bands are observed, with the difference, however, that the entire spectrum is somewhat displaced. These observations, therefore, give an experimental proof for the assertion that we

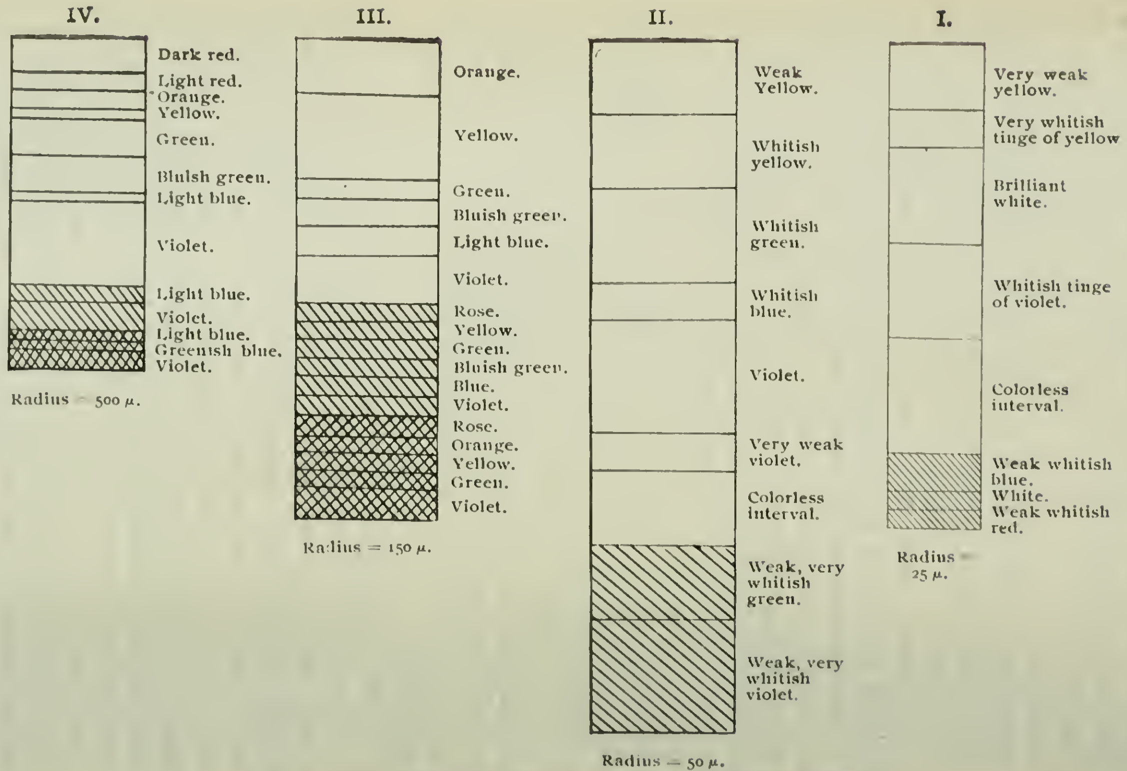


FIG. 3.—Four diagrams showing calculated rainbows (Pernter).

have to do with the phenomenon of diffraction; the further conclusion is easily drawn that in case we use white light, the different colors will overlap and thus give rise to mixed hues. Removing the glass and allowing the sunlight to fall upon the slit a phenomenon is observed which is essentially the same as the rainbow seen in nature. For we observe a long series of bands: the first shows red on the one end followed by yellow, green and violet (first bow), and the others (secondary bows) are a partial repetition of these hues.

We now proceed to the second part of the experiment. Instead of a cylinder measuring 2 to 3 millimeters in diameter, we use one of (say) 1 millimeter or a well-shaped glass-thread. The contrast is striking. The bands are broader, the colors less saturated and partly of a different succession; the blue, which before could hardly be noticed, is now prominent. Hence the phenomenon depends on the size of the cylinders. This conclusion, applied to the rainbow as it occurs in nature, gives a positive proof that the width of the entire bow, the width of the single colors and their succession, necessarily depend on the size of the raindrops. This we can understand better from *Figs. 4* and *5.* They show how the intensities of the different colors are superposed. *Fig. 5* especially gives us a fair idea of the final result—a white rainbow. (Cfr. No. I of *Fig. 3.*) In the first set of intensities the maximum of all the colors occurs almost in the same spot, hence white is produced in the main part of the principal rainbow. Between the first and second set all the colors have their minimum intensity (= 0) nearly at the same place, which explains the dark space between the principal and the first secondary bow as shown in No. I of *Fig. 3.*

Thus far the experiment affords a general proof for the correctness of Airy's theory; its performance requires neither a skillful experimentalist nor a well-furnished laboratory. However, a strictly scientific confirmation of the theory should be derived from experiments carried out with cylinders or drops of water, since it is water which in nature gives rise to the rainbow. W. H. Miller was the first to make experiments in this line; afterwards they were taken up especially by Mr. Mascart, who in 1888 published his extensive and exact researches in the "Comptes Rendus." But since in the latter experiments only monochromatic light was made use of, Mr. Pernter saw himself necessitated to employ white light in order to have his calculations corroborated by experiment. Since their results demonstrate the accuracy of Airy's theory we think it proper to present them in their essential features.

CALCULATIONS FOR $a = 500\mu$			EXPERIMENTAL RESULTS FOR $a = 500\mu$		
ANGLE.		X	ANGLE		OBSERVED COLOR.
deg.	min.		deg.	min.	
42	10	red			
42	0	red			
41	50	red			
	40	yellow	41	36	Maximum of intensity.
	30	green	41	35	Limit between yellow and green.
	20	green			
	10	green	41	7	Limit between blue and violet.
	5	blue	41	5	Beginning of the first violet.
41	0	violet			
40	55	violet			
	50	violet	40	50	End of the first violet.*
	45	blue	40	45	Beginning of the second violet.
	40	violet			
	35	violet			
	30	rose	40	30	Middle of the second violet.
	25	rose	40	25	End of the second violet.
	20	blue			
	15	bluish green			
	10	blue			
	5	rose	40	2	Middle of the third violet.
40	0	rose	40	0	End of the third violet.
39	55	blue			
	50	bluish green			
	45	blue			
	40	rose			
	35	rose	39	38	Middle of the fourth violet.
	30	blue			
	25	blue			
	20	violet			
	15	rose			

* Average of three values.

A cylindrical water-jet was passed through the centre of the spectrometer and illuminated by sunlight admitted through a very narrow slit of the collimator. The angles of the different colors were accurately measured. Of course it was a difficult task to produce a jet exactly equal to that assumed in the calculations, hence Mr. Pernter sometimes had to content himself with an approximate value. There was also some difficulty in bringing the water-column to the exact center of the apparatus; this might have caused an

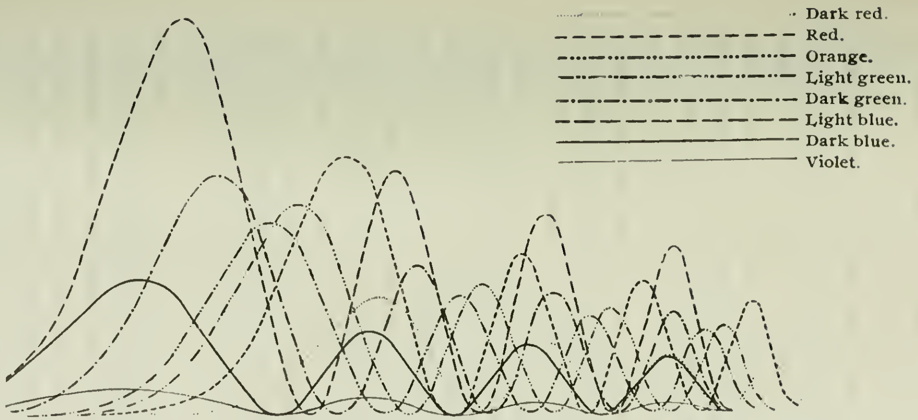


FIG. 4.—It shows how the bands of eight different colors overlap in case the radius of the drop measures 250 μ. (Pernter.)

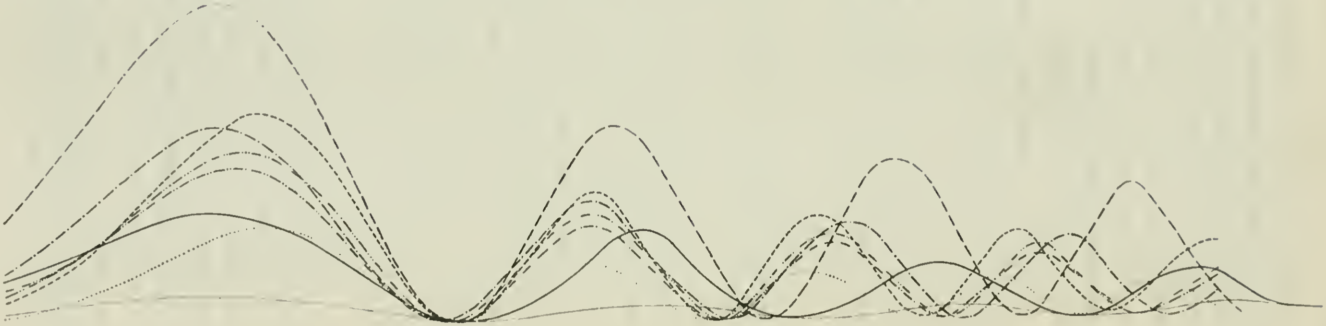


FIG. 5.—It shows how the bands of eight different colors overlap in case the radius of the drop measures 25 μ. (Pernter.)

error of not more than ± 4′. Notwithstanding all these difficulties he succeded in getting quite satisfactory data as regards the rainbows calculated for $a = 500\ \mu$ and $a = 250\ \mu$. We subjoin a table comparing the results of the calculations with those of the experiment. It is to be noted that in recording the colors seen in the experiment, violet and rose were not distinguished; x stands for the color resulting from a mixture of hues.

With $a = 500\ \mu$ the colors succeeded each other as follows: pure red, orange, yellow, green, violet, blue and the second violet; with $a = 250\ \mu$: red, orange, yellow, green, bluish green, blue, violet, rose. These data, therefore, afford the proof for Airy's assumption that the size of the raindrops plays an important part in the outcome of the phenomenon. As regards the secondary bows another interesting observation was made. With $a = 500\mu$, twenty-four were numbered: the first eight consisted solely of violet (rose) and green or light blue; after the twelfth a band almost white, but shading somewhat into yellow, was seen, and the subsequent bows showed a trace of yellow before the violet, hence the succession of hues was reversed. With $a = 250\ \mu$, eleven bows could be counted: the white band mixed with a tint of green occurred already in the fifth and afterwards the hues followed each other again in reversed order. Comparing these results we come to the conclusion that the number of visible bows decreases with the radius of the drops. The same was found true in the second rainbow; for with $a = 500\ \mu$, thirteen were observed, whilst with $a = 250\mu$, only five.

What we have said so far, may suffice for the explanation of the rainbow as ordinarily observed and known to all. But perhaps we will not act amiss by considering more in particular also the white rainbow, a phenomenon of high importance for Airy's theory, because this explains it fully, whilst Descartes' view here leaves us in the dark.

A white rainbow may not infrequently be observed on mountains and on seashores, particularly in northern latitudes. If formed by sunlight, the principal bow is made up of a brilliant white, the margins are somewhat colored, the outer showing a yellowish and orange-red, the inner a bluish-violet tinge. The secondary bows, if any occur, are separated from the principal arch by a dark space and their colors succeed one another in a reversed order; for a bluish seam lines the dark interval, whilst the red lies toward the inside.

Since a white rainbow may be formed by sunlight as well as by moonlight, we are now to investigate the causes of the phenomenon. They may be reduced to three.

The first is the weak intensity of light in case of the lunar rainbow. Since it is a known fact,* that by lowering the intensity of a color beyond a certain limit, each color as such ceases to make its own impression and appears as a grayish white, we easily understand that on account of the weak intensity of moonlight the lunar rainbow shows a whitish appearance.

It would be very interesting to find out under what conditions of intensity the rainbow-colors produce no effect on our visual organs. However, this question cannot be answered with certainty. Messrs. Abney and Festing, it is true, have shown experimentally when color disappears from our sight, but these data cannot be applied to the rainbow. First, there is no known standard to which we could refer the intensity of the rainbow-colors. Moreover, since daylight, which is variable in brightness, mixes with the colors, the sensation itself will thus be differently affected. Finally, because the air as regards dryness and moisture and the number of drops contained in a cubic meter (on which the intensity of colors depends) are variable, any estimate falls short of the reality.

A second cause is the inequality in size of the raindrops, whereby the different colors might be caused to overlap in such a way as to produce the sensation of white. Although we do not deny that this is possible, yet, since a white rainbow was never observed during a rainfall (it is assumed that it begins to rain when the drops have become at least 100μ

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* Cfr. Abney and Festing, "Color Photometry," Part III; "Philosoph. Transact.," London, Vol. 183 (1892), p. 537.

in diameter) we need not dwell any longer on this explanation.

Very small drops are the third cause.

White occurs in every rainbow, whether in the principal or in a secondary one; however, we restrict the designation of "white rainbow" to those in which white is really prominent, without excluding differently colored shades.

Before we enter upon the explanation of this phenomenon, we must answer the question, in what case a mixture of colors gives rise to the sensation of white. Since every mixture of colors results into a pure spectral color and white, it is to be ascertained what percentage of each is required to make any color as such disappear. Mr. Abney proved that this percentage is the same for all colors, each disappearing in case a white light seventy-five times stronger be added. This means that white only then appears when the intensity of the color is 1·3 per cent. of that of white. At first sight this law seems to import the impossibility of a truly white rainbow since the calculated intensity of x is never as low as 1·3 per cent. The utmost we could expect is a sensible whitish shade in case x reaches 4 per cent. and below. Hence in our explanation we have to show that x reaches the limit stated by Mr. Abney.

We must bear in mind that Mr. Abney made his experiments in a dark room, whilst the rainbow is formed in full daylight and sunshine; whence it follows that since the sunlight is white and intense in comparison with the colors of the rainbow; the percentage of x is lessened whilst that of white is increased. If, therefore, the intensity of x be near the limit, 1·3 per cent., and if daylight be added, we understand that a truly white rainbow can be the outcome.

A series of interesting experiments, carried out by Mr. Pernter, confirm this explanation.

By means of ordinary atomizers he produced a fine water-spray (the size of the drops could not be measured on account of the small quantity of water), sunlight was allowed to fall upon it, and the phenomenon observed comported well with the raindrops figured out for very small drops. Red was wanting in the principal rainbow and the orange showed a distinctly yellowish tint. Then very whitish shades of green and blue were seen, after which the violet came out more clearly as such. In full daylight these colors certainly would have given the rainbow represented in No. I of *Fig. 3;* this conclusion is corroborated by the large extension of the principal rainbow.

In another experiment the water-spray was dense enough to find the exact size of the drops. They measured 5·3 in radius. When sunlight fell upon the cloud of water-dust a splendid white rainbow was obtained, owing, without doubt, to the white sunlight which, although admitted in small quantity, increased the percentage of white enough to reach the limit for x. With $a = 8{\cdot}4\ \mu$ a white rainbow was yet obtained, the white band, however, had already decreased in width.

THE TECHNOLEXICON OF THE SOCIETY OF GERMAN ENGINEERS.

In the beginning of 1901, the Society of German Engineers (Verein Deutscher Ingenieure) began the compilation of a universal dictionary in the three languages, English, German and French. This undertaking has met with general approval and has received assistance from all quarters at home and abroad. Societies and individuals have responded generously to the invitation to collaborate and have proved their interest by the transmission of collections of technical words made by them or by promising such in the near future.

Up to now (May, 1903) there are 341 societies (42 in English, 272 in German, and 27 in French speaking countries) co-operating in the work, either by the systematical collection of technical expressions of the specialties represented by them or in other ways, especially by the acquisition of collaborators and by placing technical publications in more than one language at the disposal of the "Verein," as catalogues of firms, inventories, piecelists of machines, handbooks, etc. Through these societies the *Technolexicon* has found helpers in Great Britain, Germany, France, the United States, Austria, South Africa, India, Australia, Belgium, Canada, etc.

Among the English societies we name the following: The Institution of Mechanical Engineers, London; the Institution of Electrical Engineers, London; the Junior Institution of Engineers, London; the Society of Chemical Industry, London; the Institution of Mining Engineers, Newcastle on Tyne; the Iron and Steel Institute, London; the Society of Architects, London; the British Optical Association, London; the Optical Society, London; the Cycle Engineers' Institute, Birmingham; the South African Association for the Advancement of Science, Cape Town and Johannesburg; etc. Of American societies may be mentioned the American Society of Civil Engineers, New

York; the American Society of Mechanical Engineers, New York; American Railway Engineering and Maintenance-of-Way Association, Chicago; the American Chemical Society, Brooklyn; the Western Society of Engineers, Chicago, etc. In Germany there is first of all the large majority of the local sections of the Society of German Engineers; then there are Verein Deutscher Eisenbahnverwaltungen, the Verein Deutscher Chemiker, the Zentralverband der Preussischen Dampfkesselüberwachuugsvereine, the Verband Deutscher Patentanwälte, the Deutsche Schiffbautechnische Gesellschaft, and many others. In France we mention: Société des Ingénieurs Civils de France, Paris; Association Amicale de Anciens Élèves de l'Ecole Centrale, Paris; Société Internationale des Electriciens, Paris; Société d'Encouragement pour l'Industrie Nationale, Paris; Société Française de Photographie, Paris; Syndicat Général de l'Industrie des Cuirs et Peaux de la France, Paris, etc.

Assistance has so far been promised—and partly already rendered—by 2185 industrial establishments and individual collaborators.

The excerption of dictionaries like Sachs-Villatte, Muret-Sanders, Tolhausen, etc., and of thousands of firms' catalogues and price-lists, of handbooks, store-lists, piece-lists, customs tariffs, etc., has yielded 1,200,000 filled-out word-blanks up to May, 1903. To them will be added within the next two years the hundred thousands of words that the contribution of the collaborators will bring. For convenience sake the Society of German Engineers has provided handy note-books (each with three indices A—Z) for the collaborators to write their collections therein. These books will be called in by the editor-in-chief in the course of 1904. So far already 207 filled-out note-books have been forwarded voluntarily to the address given below.

As the contributions will be called in before 1904, all who wish to help in the compilation of the *Technolexicon* have still time and opportunity to assist in the preparation of their specialities. Contributions from all technical branches (including the handicrafts) are welcome, and it is obvious that small contributions from a host of various collaborators will be more useful than large ones compiled by a few men, who naturally cannot cover so many specialties. Attention is to be drawn to the fact that contributions in only one language are also most acceptable, though, of course, those in two or three languages are the most valuable, as also polyglot business-catalogues and other technical publications. Delayed contributions, if they arrive before the end of 1906, when we shall begin to print, can still be made use of.

The editor-in-chief will be pleased to give any information wanted. Address: Technolexicon, Dr. Hubert Jansen, Berlin (N.W. 7), Dorotheenstr., 49.

SOLDER FOR ALUMINUM.

A solder for aluminum, which forms the subject of a recent United States patent, consists of aluminum 5 parts, antimony 5 parts, and zinc 90 parts. To make it harder, use a little more antimony and a little less zinc. The solder is prepared as follows: The aluminum is first melted in a pot. The zinc is then added, and when this is melted the antimony is added. The metal is then thoroughly fluxed with sal-ammoniac. When the surface of the metal is quite clear and white it should be poured into sticks ready for use, the cinder being first removed.—*Scientific American Supplement.*

The Induction Motor and Its Engineering Capabilities.

[*A Thesis Presented to the University Faculty of Cornell University for the Degree of Doctor of Philosophy.*]

BY GEORGE L. HOXIE.

(*Concluded from page 290.*)

PART THREE.

ENGINEERING CAPABILITIES OF THE INDUCTION MOTOR.

In General.—It is the intention of the writer to discuss very briefly in this section the applicability of the induction motor to a few classes of service which may be deemed typical. In some of these cases the induction motor is an almost ideal source of power, and in some others it may be made to do the work, but only after a considerable amount of trouble. The cases which will be considered are as follows:

(*a*) Driving of manufacturing establishments which demand a service similar to that demanded by a cotton mill.

(*b*) Driving of shops similar to machine shops.

(*c*) Operating pumps.

(*d*) Operating fans.

(*e*) Driving other electrical machinery or operating as frequency changers.

(*f*) Operating cranes or elevators.

(*g*) Operating electric railways.

It may be said in general that for any service requiring a nearly constant speed the induction motor will be found suitable. For a large starting torque, together with a good speed regulation, special devices may be added. For a service requiring a variable speed, and a torque varying inversely with the speed, the induction motor is not primarily well suited and it is only with difficulty that it can be adapted to such a service.

The electrical rivals of the induction motor are three, namely, the alternating current synchronous motor, the direct current shunt motor, and the direct current series motor. For many of the uses to which the shunt motor is put the induction motor is equally good and, in some cases, preferable. The latter has about as good a speed regulation as the former, and this may be obtained with a fair starting torque and a moderate demand for current. The induction motor has no parts demanding such constant attention as is required by the commutator of the direct current machine. The efficiency is about the same in each case. The advantages of current supply and distribution are with the polyphase currents required by the induction motor.

The alternating current synchronous motor has several advantages over the induction motor. Its speed regulation is absolute and its efficiency is somewhat better. The power factor of the synchronous machine may be made unity or it may be made to draw a lagging or a leading current, as is desired. On the contrary, such a machine is in general not self-starting and, if it loses at all in speed, say on a heavy overload, it will stop. In addition, the synchronous motor requires a direct exciting current.

The direct current series motor gives a torque approximately changing inversely with the speed. It is therefore well suited for traction work of all kinds, and for cranes, hoists, elevators, etc. The induction motor could not be a competitor at all for this class of service, except that its small cost for maintenance and the flexibility of the polyphase system which it uses, have led to the development of special devices by means of which a motor not primarily suited to a service may yet be made to answer its requirements satisfactorily.

(*a*) *For Driving Cotton Mills.*

Cotton machinery requires a drive that shall run at the most uniform possible speed. It is quite desirable that the motive power shall be self-starting, but frequent starts and stops are not necessary. It is very undesirable that an electrical machine should be used about which arcs or sparking may occur. It is sometimes desirable to start up all the machinery of the establishment together, as is the general practice where the power is transmitted by shafting and belts.

All of these conditions point toward the employment of the induction motor, and such motors are largely used in practice. It has no serious competitor in this field, except perhaps the synchronous motor, and the difficulties of starting almost preclude the use of the latter.

(*b*) *For Driving Machine Shops.*

In a machine shop the conditions are quite different from those just discussed. There are usually tools of quite different characteristics to be driven, and many of the tools must be capable of operating at any one of several speeds. Two methods of electrical driving are in use and are found quite satisfactory. They are known as "group driving" and "individual driving." The former system is one that resembles to a considerable degree the method, formerly universal, of driving from a single source of power by means of shafting and belts. The tools are arranged in groups and each group is driven from a single motor. Usually a short-line shaft is used for each group and each machine is supplied with its own countershafting and belts. The number of tools driven from a single motor may be many or few, according to circumstances. Some groups may require the use of a large motor, while other groups may consist of single tools. The use of the group system, as a whole, does not therefore preclude individual driving in particular instances, though it usually involves an electrical installation that is not the best possible one for individual driving. Since electrical driving has for the most part been introduced into shops formerly driven through shafting, the method of group driving has merely involved a division of motive power into several units and a change to electric motors for those units. The expense of such a change is not great and the shock to the conservatism of owners and employees is a minimum. Group driving is therefore now in extensive use.

With group driving, the motor requirements are for a constant speed, some starting torque, and a minimum of attendance. These requirements are met in the best possible manner by induction motors, and, except in special cases, nothing else should be considered for a new installation.

What is known as individual driving means the employment of a separate motor for each tool that is to be driven. The advantages of this system are many and great. The initial expense is, however, considerable, and the old shafting, counter-shafting, belts, etc., that are usually in place, cannot be used. The conservatism of owners and managers has tended to prevent such a radical departure from the earlier practice, and for these reasons the system of individual driving has not been adopted to the fullest extent. In the shops of a few electric companies, however, elaborate installations of this sort have been made. In these cases the equipment serves as a valuable advertisement, and is useful from this point of view as well as for its intrinsic merits.

The requirements of a motor for individual driving differ with the character of the tools to be driven. In most cases not only is a wide range of speed necessary, but the tool must be capable of operating continuously at any of its possible speeds. The induction motor may be used in these cases, and the power transmitted through cone pulleys, back gears, etc., but it is not suited for the most direct connection to the work, and it cannot compete, for convenience in this respect, with the multiple voltage, shunt motor system. For the tools that run always at one speed, the induction motor is of course entirely satisfactory, but since only one system is likely to be installed in any given shop, and that one should be the one best adapted to all requirements, it is not likely to be found desirable to use this motor in machine shops where the electric drive is to be of the most complete character. It probably will be found best for those shops in which group driving, or driving from counter-shafting, is to be used. With certain wood-working machinery the induction motor is much to be preferred, since there is little danger of its starting a fire, even when surrounded by combustibles.

(*c*) *Operating Pumps.*

For the electrical operation of pumps, the induction motor leaves little to be desired. It is particularly satisfactory when it is necessary to run the pump in an out-of-the-way place that is seldom visited. Large numbers of these pumps with induction motors are used for irrigation in the Western regions, and in many cases they are started and stopped from distant points, and visited only at infrequent intervals for the purpose of supplying oil. No other motor is in any degree so satisfactory for this as is the induction motor.

(*d*) *For Operating Fans.*

Much the same advantages are found for the induction motor when a fan is to be operated as were mentioned in the preceding paragraph, The ventilating system of a building must operate with as little attention as possible, and except in the case of the largest buildings, such attention as can be had is likely to be of a rather unskilled character. Between two motors rendering equally efficient service, one of which starts or stops with the throwing of a switch, and requires no other attention beyond an occasional oiling, while the other requires a little more trouble to start and stop, the same oiling, and constant attendance upon a commutator, there can be little question which will be chosen. The advantages of transmission besides are all on the side of the induction motor.

(*e*) *For Driving Other Electrical Machinery.*

Owing to the great advantages of polyphase alternating currents for the transmission of energy, few large generating stations are now built that do not involve a generation of such currents. At the same time it is practically necessary in many cases, that some form or forms of direct current shall be supplied, and occasionally it is desirable to make use of alternating currents of more than one frequency. The generating machinery, however, must be installed in large units if the best economy is to be obtained, and besides this, the simplicity and ease of operation are much increased if all the generators are of the same type. These conditions lead in many cases to the installation of generating units to supply polyphase alternating currents only; the other forms of electrical energy being obtained from auxiliary machinery. This auxiliary machinery may be divided into three general classes: (1) Rotary Converters; (2) Motor Generators; (3) Frequency Changers.

Motor Generators.—Motor generators may be driven from any kind of electrical supply and may furnish any sort of electrical power. The only varieties that are of any present interest are those which are driven from a source of polyphase alternating currents. In this case there are two possibilities. They may be driven by synchronous motors, or they may be driven by induction motors. Each method has some advantages, and it is only a special study of each particular case that will enable one to decide which is best. The advantages of the induction motor are its ease of starting, and its small charge for attendance and repairs. Since the generator side of the motor generator set may always be brought up to speed before being loaded, it is unnecessary to use a motor with wound secondary, or slip rings.

The advantages of the synchronous motor are its absolute uniformity of speed (supposing the supply to have a constant frequency), and its high and regulable power factor. It has also a slight advantage in efficiency.

Considering first the question of starting, we find that this is not one of serious difficulty in either case. Since the starting is not done under load, it is possible to start up the synchronous motor by the induction motor action due to eddy currents induced in the pole pieces, or in the copper bridges sometimes used between the poles, or surrounding the poles. It is also possible to start the synchronous motor by means of a small auxiliary induction motor. In some cases, too, it is possible to start a motor generator set from the generator end. It is therefore true that, so far as the question of starting goes, there is no very serious objection to the synchronous machine.

As to speed regulation, the synchronous motor is preferable, but not greatly so, since an induction motor for this purpose need not have a high starting torque, and it may therefore be given an exceedingly good speed regulation. Furthermore, a slight drop in speed with increase in load may often be compensated for by compounding the generator end. This may always be done where the generator is a direct current machine for constant E.M.F. The direct current machine for constant current is largely run motor driven, but this type of machine does not demand an exceedingly close speed regulation.

The item of attendance and repairs is less for the induction motor, but the attendance feature is of small importance, since the generator end of the machine is always such as to require skilled attendance on its own account. The repairs should be quite small with either type of machine.

Concerning the power factor the advantages are greatly in favor of the synchronous motor. The power factor of this motor may be controlled by varying the field excitation. In some instances it has been found possible to keep the power factor on a line near unity, even when it was supplying current to induction motors, by drawing a leading current from it to synchronous motors. The value of this feature of the synchronous motor depends very largely upon the local conditions under which the plant may be installed. This is the only item of great importance that is in favor of the synchronous motor.

A minor feature which is to the disadvantage of the synchronous motor is its requirement of an auxiliary direct current exciter.

Frequency Changers.—The only practical type of frequency changer now in use is one of the induction-motor class. Such a frequency changer is in part an alternating-current transformer and in part an inverted induction generator.

Let us imagine that the secondary of an induction motor is blocked so that it cannot turn, and that the primary is excited normally by polyphase currents. We will assume that the motor has a wound secondary, the circuits of which terminate in slip rings. Under these circumstances the motor will act like a simple alternating current transformer with its secondary circuit open. If a resistance load be connected to the slip rings, the motor will act like a transformer that is delivering current, but in this case the regulation of the transformer would not be good, since it would have considerable magnetic leakage. It might be so used, however, and would give fair results if of proper design. The primary and secondary frequency would of course be the same under these circumstances, while the ratio between the primary and the secondary E.M.F's would depend upon the number and arrangement of the turns. We may assume this ratio to be unity in a particular case.

If the motor is permitted to turn at half-speed we shall have an alternating current transformer, but one in which the secondary frequency is half that of the primary. The secondary E.M.F. is also reduced one-half. If the secondary be mechanically driven at half-speed in the opposite direction, its frequency and E.M.F. (neglecting leakage) are increased one-half.

Since the mechanical motion, when the secondary is driven backwards, is in a direction opposite to that of the resultant primary flux, it follows that electrical energy is transferred from the primary to the secondary. For the same reason it follows that the mechanical work done in driving the secondary also appears as electrical energy in the secondary circuit. If we neglect various losses, we may say that the part of the total energy that comes from the primary is, when compared with the total energy, in the ratio of the primary frequency to the secondary frequency. Also the ratio of the power supplied mechanically, to the total power output of the secondary, is the ratio of the frequency added by the mechanical driving to the total frequency of the secondary.

If, therefore, the primary frequency in a given case be 25 and the secondary frequency is to be 50, the secondary must be driven backward at what would be full synchronous speed in the opposite direction. The output of the frequency changer would be (neglecting losses) half supplied from the primary and half from the driving motor. The secondary conductors would have twice the cross-section of those of the primary if the windings were otherwise alike.

Frequency changes are generally driven by synchronous motors. They are not particularly satisfactory commercially except in special cases, since the large magnetic leakage makes regulation difficult.

(*f*) *For Operating Cranes, etc.*

The induction motor would probably not be used upon cranes and similar classes of work, except for the great desirability of polyphase motors for other work and the inconvenience of maintaining two separate systems of electrical supply. These considerations have, however, led to the use of the induction-crane motor in many cases. The performance of machines of this sort, as to drop in speed under load and current and power required for light running, are given in the preceding table. The motors, if of squirrel-cage construction, are built with high resistance end rings, and while they give, therefore, a large torque they are not very efficient machines. In *Fig. 19* is given a comparison of the efficiency curves of a series, direct current-crane motor, and an induction motor, built for crane work and of about the same capacity as the former. The induction motor is one having a squirrel-cage rotor. The efficiency of the direct-current machine is considerably the better through its entire range, and that motor has a wide range of operation over which its efficiency is quite good. The induction motor reaches its maximum efficiency very abruptly. Both of these motors were made by the same company.

Speed variation in a motor of this sort is accomplished by the use of a special compensator that provides varying impressed pressures. This is not an efficient means of regulation, since the torque of such a motor varies with the square of the impressed pressure. Crane motors with wound secondaries may be made to give a variable speed by the variation of a resistance in series with the secondary. This again is inefficient, though it provides a highly satisfactory torque curve. The motor is not so desirable mechanically since this method of control is considerably more complex. The motor with squirrel-cage secondary is probably the more desirable, on the whole, for this class of work.

It must not be supposed that the induction motor has no intrinsic advantages for crane work over the series direct

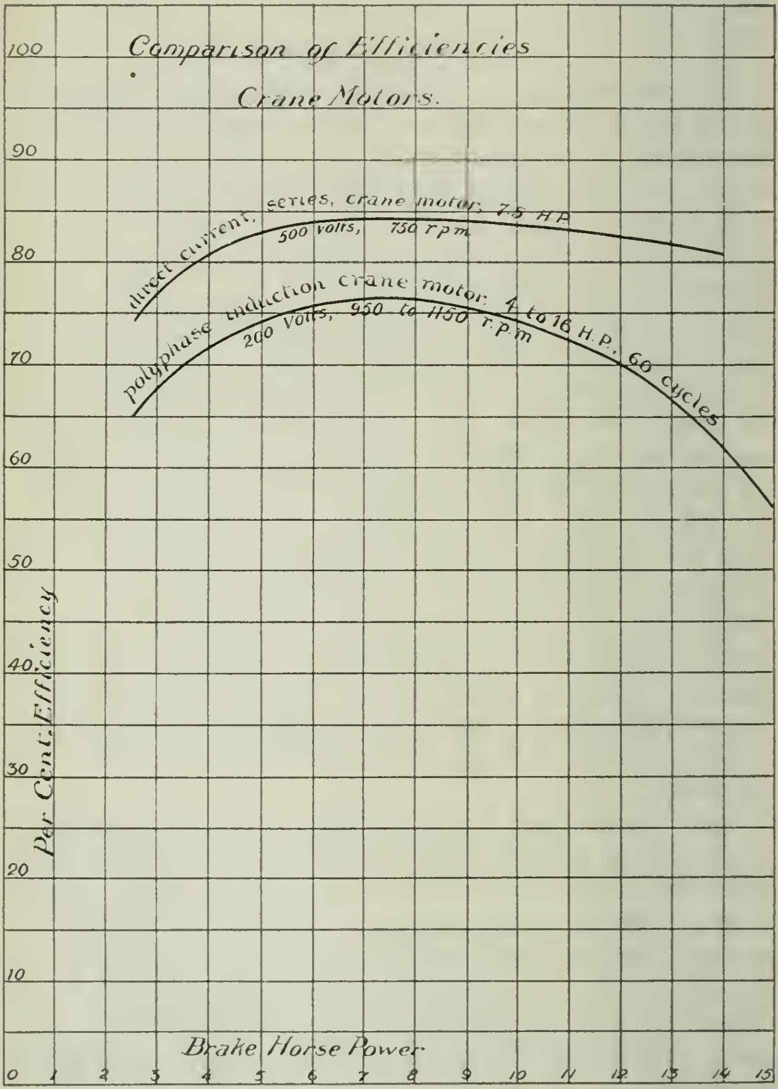


FIG. 19.

current motor. It has the very great advantages of simplicity and the capacity to withstand a great amount of ill treatment. Its performance otherwise is not so satisfactory as is that of the series motor.

(*g*) *For Operating Electric Railways.*

It is very hard to express an opinion as to the adaptability of the induction motor to general railway work. The actual use of this motor has been quite limited, and such installations as have been made are too recent to be accurately judged. No examples of this sort are found in the United States, and in Europe the roads which are so operated do not present problems at all resembling those which are most commonly met with in this country. The promoters of the induction railway motor, or of a polyphase system for electric railway operation, have evidently a considerable degree of confidence in the system. One large European firm (Ganz & Co.) recently made a vigorous effort to obtain the contract for the electrification of two underground railway systems in London, and their proposition covered a complete system for the polyphase operation of those roads, induction motors being used exclusively. It seems probable that such a proposal would not have been seriously made by a large and responsible company had any doubt as to its feasibility existed in the minds of their engineers.

It is easy to state the theoretical advantages of the induction motor and of the direct current motor. When one turns to the practical aspect of the question, however, one finds statements from eminent experts that are flatly contradictory as to matters of fact. The final answer to these disputed questions can only come after the completion and operation (or failure) of a road resembling that of a surface or underground line in one of our great cities.

From the theoretical point of view, we may study the subject under the following heads:

(1) Initial Cost.
(2) Methods of Control.
(3) Maintenance of Schedule.
(4) Operating Convenience.

(5) Efficiency.

Many other things might be discussed, but these are sufficient to bring out a comparison of the theoretical qualities of the two classes of motors.

(1) *Initial Cost.*

Both systems are likely, in large installations, to make use of the same type of generating stations. The main transmission lines would probably also be the same. With the direct-current system expensive sub-stations are necessary and the lines from the sub-stations to the motors must have a large current-carrying capacity.

With the polyphase system any sub-stations used are pressure-transforming stations only and are comparatively inexpensive. They do not require attendance. The lines from the sub-stations to the motors may be much smaller than for direct currents, since the cars may safely take current at high pressure.

The induction motors should be the cheaper, although it is not practicable to use motors having squirrel-cage secondaries. The controlling devices are very complex in either case. Those for use with direct currents have been standardized and are manufactured in large quantities. If polyphase motors were to become widely used for traction purposes it seems probable that their controllers could be manufactured more cheaply than those for direct current motors. From the standpoint of initial cost, therefore, the advantage should lie with the polyphase system. This conclusion is verified by a comparison of the bids for the electrification of the two London roads previously mentioned.

(2) *Methods of Control.*

A traction motor must be capable of giving a powerful torque on starting or at low speeds. To secure this with a single motor, if of the induction type, it is necessary to insert a large resistance in its secondary. The motor is then quite inefficient. This method may be compared with the resistance control of a direct-current series motor.

A system known as the "cascade system," or as a system of "concatenated control," has been somewhat used and is strongly recommended by its sponsors. This system is somewhat analogous to the series-parallel control which is so generally used with direct-current motors. In the cascade system two motors are used, and one of them is supplied with current from the secondary of the other. Additional regulation is secured by a resistance in the secondary of the last motor. This arrangement is only intended to be used between zero and half-speed of the car. At half-speed of the main motor its secondary frequency is half that of the primary, and the second motor, if similar and running at the same speed, is running at synchronous speed. The first motor is really acting partly as a motor and partly as a frequency changer for the second motor. A resistance in the secondary of the second motor produces about the same effect as if it were placed in the secondary of the first motor, so far as the operation of that machine goes. This is more nearly true as the magnetic leakage of the two motors is diminished. It is, therefore, the practice with the cascade system to use motors having as few poles as possible and an excessively short air gap. There is some question as to the safety of this short air gap for traction work. The frequencies used are low, often 15 cycles per second.

Since the induction motor, when driven slightly beyond synchronism, becomes a generator, it is possible to return power to the line on long down grades by permitting the car to run downward a few per cent. faster than upward. This property seems to be of value only in special cases.

(3) *Maintenance of Schedule.*

Since for ordinary running the motors must operate at a speed that is close to synchronism, trains operated by them will either run at a uniform speed or will stop. It therefore follows that if the motors are adequate to the work a train cannot lose time while running. This has been urged as a great advantage for the induction motor. It is equally true, however, that if a train be delayed from any cause, no time can be made up while running. Experience alone will determine which of these features is the more important.

(4) *Operating Convenience.*

The polyphase system possesses a great advantage, in that no attendance, beyond an occasional inspection, is demanded by its sub-stations. The motors have a further advantage in not possessing commutators. The controlling devices are essentially no more complex than those for direct currents. The necessary use of two sliding contacts, or trolleys, is a considerable disadvantage.

(5) *Efficiency.*

In considering the question of efficiency, the entire system should be considered in each case. The progress of the power from the generating station to the motors may be taken as the same up to the sub-stations. The power factors up to that point may be nearly alike if the rotary converters, which we will assume for the direct current system, be compounded. At the sub-stations, the direct-current system loses from 5 to 10 per cent. in the rotary converters. There is no corresponding loss in the other system. The loss between the sub-stations and the motors would rarely be less than 10 per cent. with the direct current, and would often be more. For the polyphase system this loss should be under 10 per cent. At the motors, the running efficiency should be about the same in the two cases. The starting conditions would favor the direct current.

In conclusion, it may be said that the use of the induction motor is undoubtedly increasing, and it is possible that it may ultimately be used for traction purposes upon the large trunk lines of the country.

ELECTRICAL SECTION.

Stated Meeting, held Thursday, April 23, 1903.

Some Practical Points in the Design of Direct-Current Dynamo-Electric Machines.

By Cecil P. Poole, Member A.I.E.E.

The design of direct-current dynamo-electric machines has become a somewhat hackneyed subject of late, and but for the fact that some of the practical points which it is the object of this paper to present have not hitherto been made public, the author would certainly not have the temerity to discuss the question.

It is, of course, well known that the output of a direct-current machine is limited in practice by either heating or commutation, or both. It has been the author's observation that commutation sets the limit in a larger proportion of machines than does heating, especially when the modern well-ventilated construction is used. That bad commutation is due to a combination of armature reaction on the field and the inductance of the coil undergoing commutation, is so well understood as to require no discussion. It is also a familiar fact that the interposition of resistance between the terminals of a coil short-circuited for commutation, as by using carbon brushes, or high-resistance commutator risers, etc., usually assists commutation by reducing the time constant of the short-circuited coil. But it is also true that machines of commercially practical character may be calculated beforehand with reasonable certainty as to their sparking limit, without taking into consideration the resistance of the coil connections and brush faces beyond using certain constants for machines which are to operate with carbon brushes, and others in the calculation of machines to be operated with metal brushes.

Since sparking is due chiefly to the counter E.M.F. of inductance in the coil undergoing commutation, or more properly the reactance E.M.F. of the coil, good commutation depends primarily upon the strength of the field in the commutating zone near the tip of a field magnet pole. The ratio

$$\frac{e_c}{e_x}$$

is the very best criterion of sparkless commutation, e_c representing the average E.M.F. induced in the short-circuited coil during commutation, and e_x its average reactance E.M.F. during that period. The larger this ratio, the better the commutation. The value of e_c depends of course upon the strength of the exciting force that is applied to the air-gap, and negatively upon the weakening effect of the armature ampere-turns.

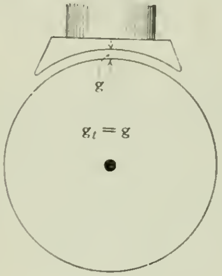


Fig. 1.

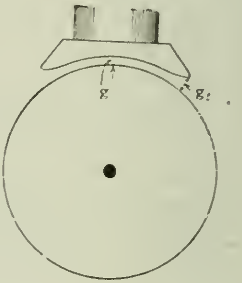


Fig. 2.

If there were no armature reaction, the flux density under a pole-tip might be considered approximately equal to the average density over the whole tip for pole-faces concentric to the armature core throughout their entire span, as in *Fig. 1*. And, representing the density of the commutating flux by B_c, the average density over the whole pole-face by B_p, the length of the air-gap under a tip by g_t, the principal air-gap under a concentric pole-face with slanted tip faces, as in *Fig. 2*, and the mean air-gap under a pole-face eccentric to the armature, as in *Fig. 3*, by g, it would be fair, for purposes of comparison, to assume the general relation

$$B_c = B_p \frac{g}{g_t}.$$

This might, of course, be reduced to $B_c = B_p$ for *Fig. 1*, but there is no gain in the reduction, in view of subsequent developments. On this basis, the E.M.F. induced in a coil, and available for reversing the current in it against its self-induction, might be taken as

$$e_c = B_p \frac{g}{g_t} D \pi L_p 2t \frac{r.p.m.}{60} 10^{-8}$$

$$= \frac{\pi}{30} B_p \frac{g}{g_t} D L_p t \, r.p.m. \, 10^{-8};$$

in which

D = Armature core diameter.
L_p = Pole-face length, axially.
t = Turns per armature coil.
$r.p.m.$ = Revolutions per minute.

With a load, however, there will be $\frac{i w \lambda}{P}$ ampere-turns on the armature setting up a magnetic stress along the path indicated by the dotted line in *Fig. 4.*

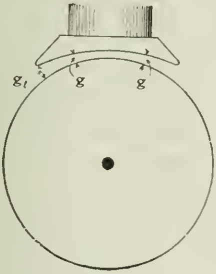


FIG. 3.

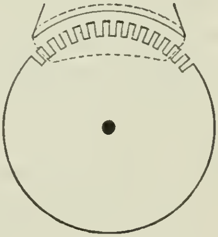


FIG. 4.

i = Amperes per armature wire.
w = Total number of armature wires.
P = Number of magnet poles.
λ = Polar arc ÷ pole pitch; in the case of skewed or pointed or rounded pole-tip edges, the *average* polar arc ÷ pole pitch.

These ampere-turns on the armature may be considered capable of producing a flux between the pole-tips and the armature core of a density,

$$B_d = \frac{i w \lambda}{K_p P g_t}$$

K_p being a constant the value of which depends on the degree to which the pole-piece and armature core are magnetized by the field winding, and the shape of the pole-tip edges. Ordinarily it ranges from unity to 1·05, and in most cases is negligible.

The net strength of the field under a commutating pole-tip, therefore, may be approximately expressed by the following equation:

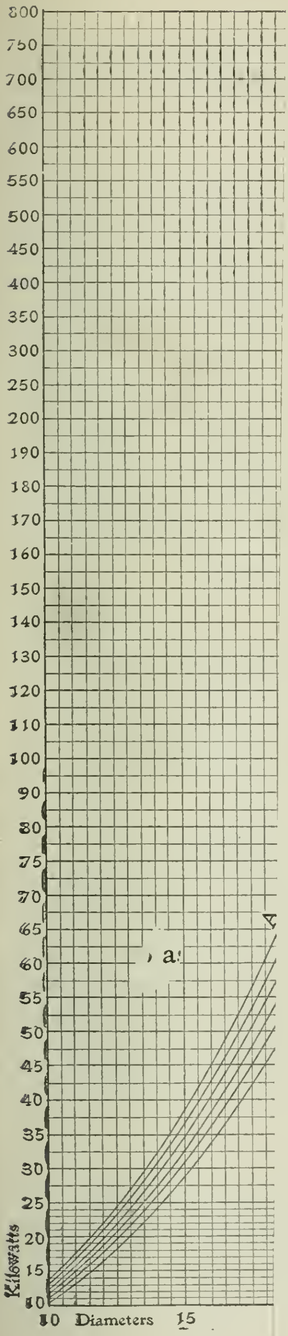
$$B_c = \left(B_p \, g - \frac{i \, w \, \lambda}{K_p \, P} \right) \frac{1}{g_t} \qquad (1)$$

Accordingly, the commutating E.M.F. induced in a coil undergoing commutation, may be approximately calculated by means of the formula:

$$e_c = \frac{\pi}{30} \left(B_p \, g - \frac{i \, w \, \lambda}{K_p \, P} \right) \frac{D \, L_p \, t \, r.p.m. \, 10^{-8}}{g_t} \qquad (2)$$

It is important to call attention, however, to the fact that this expression will not give sufficiently close results with relatively low magnetic densities in the roots of the armature core teeth, nor for machines in which the distance between adjacent pole-tips (of opposite sign) is less than 12 g_t for small sizes or 15 g_t for larger ones, and in which the maximum air-gap is more than 1·5 g for slanted edges as in *Fig. 2*, or eccentric pole-faces like *Fig. 3*. Since designs violating these restrictions are not at all common, the usefulness of the equations is not particularly impaired by having to observe them. It will be found good practice to make ratio of pole-tip proximity to pole-tip air-gap not less than 15 for machines having armatures 24 inches or more in diameter, and to reduce the minimum ratio progressively to 12 at a diameter of 18 inches, thus:

Armature Diameter.	Inter-polar distance ÷ Air-gap under pole-tip.
18 ins. or less	12
19 ins.	12½
20 ins.	13
21 ins.	13½
22 ins.	14
23 ins.	14½
24 ins. and over	15


800
750
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500
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250
200
190
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170
160
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130
120
110
100
90
80
75
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35
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Kilowatts
10
Diameters
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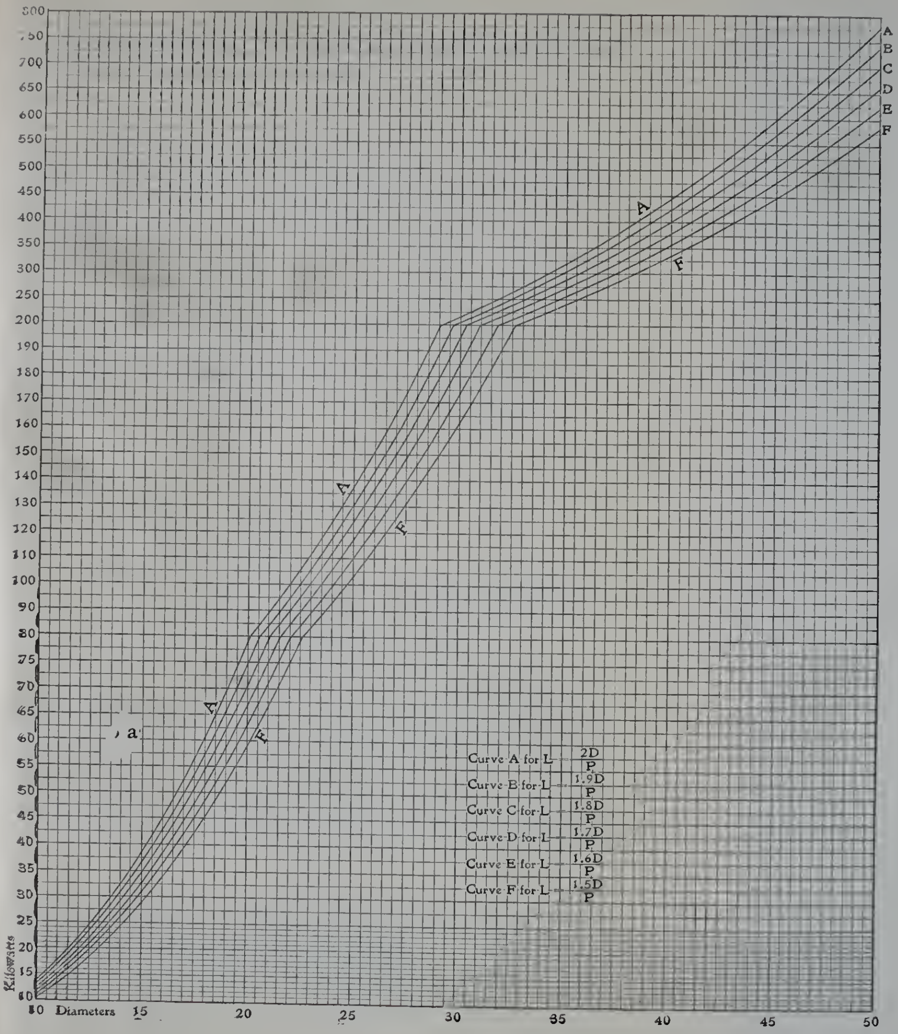
a:
4


Kilowatts
800
750
700
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170
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130
120
110
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90
80
75
70
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55
50
45
40
35
30
25
20
15
10
Diameters
10
15
20
25
30
35
40
45
50
A
B
C
D
E
F
A
F
A
F
A
F
Curve A for L = 2D/P
Curve B for L = 1.9D/P
Curve C for L = 1.8D/P
Curve D for L = 1.7D/P
Curve E for L = 1.6D/P
Curve F for L = 1.5D/P

Having a guide as to the magnitude of the commutating E.M.F., e_c, the approximate value of the ratio,

$$\frac{e_c}{e_x},$$

may be derived by following the method established by Messrs. H. F. Parshall and H. M. Hobart for estimating the reactance E.M.F., e_x. No method for determining the actual reactance of a coil under commutation has ever been made public, nor has any investigation of the exact manner in which the short-circuit current varies under different conditions ever been published, so far as the author's knowledge goes. Assuming a variation according to the sine law, which is admittedly incorrect, but is the only basis thus far suggested, the reactance E.M.F. of a coil undergoing commutation may be estimated by means of the formula

$$e_x = 6{\cdot}66\ L_a\ i\ t^2\ c\ \frac{D_c}{b}\ r.p.m.\ 10^{-8} \qquad (3)$$

in which

L_a = Gross armature core length.
i = Current per coil.
t = Turns per coil.
c = Maximum number of commutator segments simultaneously in contact with one brush.
D_c = Diameter of commutator barrel.
b = Thickness of each brush, if set radially.

The brush "thickness" is the chord of the arc of contact at the brush face, and is considered because it is more convenient to ascertain it than the length of the arc of contact, which would be the correct measurement if it were possible to deduce exact values for the other factors.

Substituting the equivalent for e_c given by equation (2) and that for e_x given by equation (3), and substituting

$$\frac{w}{2\ C}$$

for t (C = number of armature coils), after cancelling common factors, the following is obtained:

$$\frac{e_c}{e_x} = \left(\frac{B_p\ g}{i\ \ w} - \frac{\lambda}{K_p\ P}\right)\frac{D\ b\ C}{D_c\ c\ g_t}\cdot\frac{1}{31{\cdot}8} \qquad (4)$$

For use as a criterion of commutation, it is more convenient to write:

$$K_c = \left(\frac{B_p g}{i\,w} - \frac{\lambda}{K_p\,P}\right)\frac{D\,b\,C}{D_c\,c\,g_t} \qquad (5)$$

In machines having carbon brushes, the value of K_c should not be much less than the value that the derivation of the formula gives if the brushes are to have a slight lead; 30 is a good value for K_c in such cases, and with a considerable lead, the value of K_c may be as low as 20 for fixed brushes. For generators requiring adjustment of brushes for load variation (which is scarcely a commercial condition), the formula is not a reliable criterion owing to the wide differences in the values of B_d and B_c in different machines having the same values of B_p and g.

The author has applied this criterion to eighteen machines, and found it to be on the safe side by a moderate margin in fifteen out of the eighteen cases, and by a large margin in two of them; in the remaining case the formula failed utterly, and further investigation revealed the fact that the machine—a 125-volt, 1500-kilowatt dynamo—"ran sparklessly with fixed brushes *almost up to full load*," but the brushes had to be readjusted beyond that point. The exact proportion of full load carried without brush readjustment was said to be "about 80 per cent."

The formula indicates that the oft-repeated statement to the effect that the number of commutator segments should be as high as may be commercially practicable is not unconditionally correct. As an inverse indication of the number of turns per coil, the number of coils should, of course, be large, but after one has got down to one turn per coil, increasing the number of coils beyond a certain point is actually detrimental, as an analysis of the relations

$$\frac{b\,C}{D_c\,c}$$

and

$$\frac{B_p}{i\,w}$$

in the formula indicates. With a given brush thickness and commutator diameter, increasing C beyond the point where it will change the value of c is disadvantageous, unless the machine is already well within the sparkless limit, in which case nothing will be gained ordinarily by increasing C. There is a minimum value for C, however, below which it is not safe to go on account of the amplitude of oscillatory reaction by the successively short-circuited armature coils upon the increased magnetic field in the commutating zone. Just what this limit is, the author has never found it necessary to determine. Mr. Kapp, the well-known European engineer, determines it by means of the formula

$$\frac{C g}{D (1 + k)} \geqq 0 \cdot 6$$

for carbon brushes; k representing $b \div$ thickness of one commutator segment and mica strip. This, however, is based on certain conditions and criteria, and is not universally applicable. Nevertheless, it indicates a good condition if the machine is at all conventional in point of air-gap density, armature ampere-turns per pole, etc. Sparkless machines have been built, however, in which Mr. Kapp's constant was as low as 0·4. The author has found it usually sufficient to make the number of coils and commutator segments of a dynamo or a very large motor satisfy the criterion

$$C \geqq 1 \cdot 6 \, P \sqrt[3]{E^2} \tag{6}$$

E being the E.M.F. measured at the brushes, under full load. For small motors the number of segments may be much lower than this formula would make it, but small motors constitute an exception to almost every rule. For motors of moderate size, the number of segments may be

$$C \geqq 0 \cdot 8 \, P \sqrt[3]{E^2} \tag{6a}$$

and for motors of 30 to 100 horse-power

$$C \geqq 1 \cdot 2 \, P \sqrt[3]{E^2} \tag{6b}$$

All of these formulas are merely for general guidance in preliminary calculations to avoid starting out with too low a value for C. If the machine, when finally completed on paper, meets the requirements of equation (5), there will be no probability of having too small a number of commutator segments.

Two short formulæ of criterion used by the author in "roughing out" designs are

$$\frac{B_p P g}{i w \lambda} \geqq 2{\cdot}5 \tag{7}$$

and

$$\frac{B_p D b}{i c t D_c} \geqq 190 \tag{8}$$

These values are not general, but one can easily deduce the proper values for any class of design, and they will serve admirably for preliminary criteria of other designs of the same class but different sizes.

The foregoing discussion is not intended, so far as formulæ (1), (2), (4), (5) and (8) are concerned, to apply to motors of the reversible class, such as street railway and elevator motors. Since in this type of machine the brushes are set midway between the point at which they would be set for rotation continuously in one direction and the position they would occupy for rotation continuously in the opposite direction, commutation cannot be assisted by means of the magnetic fringe under the "trailing" pole-tips. In motors of this class, successful commutation depends upon the smallness of the inductance of the commutated coil and the absence of interference by the field flux. Formulæ (3) and (7), therefore, are useful in designing reversing motors; the value of e_x in general should not exceed 3 and the value of the right-hand member in formula (7) should be 3·5 instead of 2·5. The author has found in actual practice that a minimum ratio of 4 invariably gives satisfactory results, even when the value of e_x is appreciably higher than 3, and rather than be restricted to this low figure, has adopted the expedient of using 4 as the minimum value of the ratio

$$\frac{B_p P g}{i w \lambda}.$$

DESIGNING AN ENTIRE STANDARD LIST.

In working out designs for special machines and most direct-connected machines, each case must be considered alone, as a rule. With a full list of belted machines to be worked out, however, much time may be saved by laying down at the outset certain general relations to be applied to the whole list, and this method also produces more consistent results than that of designing each machine separately. Nearly ten years ago,* the author advocated this practice, and also the separation of the formulas for output into two groups; one containing factors constant for the whole line, and the other including the variable factors. This method, however, is applicable only to a limited range of sizes, since it involves working with a constant pole-face density and peripheral speed. A modification of the older method that is applicable to a line of almost unlimited range has been devised by the author, and applied satisfactorily in several instances. This consists in working with the same magnetic densities in the iron paths of all sizes of machines and expressing as many values as possible in terms of the armature diameter.

The formula for electromotive force induced in any direct-current armature may be written

$$E = D \pi L_p B_p \lambda \frac{w}{p} \frac{r.p.m.}{60} 10^{-8},$$

in which all symbols previously used have the same significance as before; p represents the number of paths through the armature winding, and the use of the reciprocal of this number as a factor in the equation makes it applicable to all commercial classes of armature winding. Inasmuch as the total current delivered by the armature is equal to $i\,p$, the formula for total generated power, in watts, may be written

$$W = D \pi L_p B_p \lambda\, i\, w \frac{r.p.m.}{60} 10^{-8}.$$

Now it is entirely rational and practical to make the pole-face density and the speed proportional each to some power

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***Vide Electrical Engineer*, December 6, 1893.

of the armature diameter. It is an obvious fact that high peripheral velocity is economical, but it has been demonstrated by experience that small machines cannot be given as great peripheral velocities as large ones; if a 10-kilowatt machine, for example, were operated at the same peripheral velocity as a 250-kilowatt machine, the speed rate in revolutions would be undesirably high, or else the diameters of the machine would be absurdly great. The author has found the relation

$$r.\,p.\,m. = 5{,}000 \div D^{\frac{2}{3}} \tag{9}$$

to be practical over a wide range, and it has the advantage of entailing only simple arithmetical computation. The value of

$$D^{\frac{2}{3}}$$

may be taken directly from a table of squares and cubes, and the reciprocal of double this value, obtainable from a table, will be the revolutions per minute ÷ 10,000.

The pole-face density may be approximated in preliminary calculations by means of the equation

$$B_{\mathrm{p}} = 34{,}380\ D^{\frac{1}{6}} \qquad 0)$$

Any coefficient between 33,000 and 36,000 will give good practical values; the value 34,380, which will seem academic at first glance, has been chosen for a purpose that will appear presently. Table I shows the results obtained from the application of these two formulæ through a pretty wide range of diameters, and will serve, in the author's opinion, to indicate their practical character. It is scarcely necessary to point out that the values thus obtained are not intended to be used rigidly. Whenever it is practicable to do so, the author adopts the nearest rational speed rate, as given in the table, but it frequently develops in the final refinements and compromises between conflicting *desiderata* that a slight departure from the preliminary speed value is advisable. The preliminary value for pole-face density nearly always must be modified somewhat to suit other conditions.

Substituting in the formulæ for E.M.F. and power the equivalents of *r.p.m.* and B_p as given by formulæ (9) and (10), one obtains the very simple preliminary equations:

$$E \doteq 0{\cdot}09 \sqrt{D}\, L_p\, \lambda\, \frac{w}{p} \tag{11}$$

and

$$W = 0{\cdot}09 \sqrt{D}\, L_p\, \lambda\, i\, w \tag{12}$$

from which it will be evident that the coefficient in equation (10) was given its particular value in order to simplify the coefficient in these last two equations.

In order to get at the approximate armature dimensions without involving the likelihood of selecting dimensions that must be afterward changed radically on account of commutation considerations, equations (7) and (12) may be combined, substituting in the latter the second number of the following transposition of equation (7)

$$i\, w\, \lambda = \frac{B_p\, P\, g}{2{\cdot}532},$$

and expressing B_p in terms of D, as before. The value of g may be taken as

$$g = 0{\cdot}018\ D^{0{\cdot}8333} \tag{13}$$

and using this equivalent, the following preliminary formula is obtained:

$$Kw. = 0{\cdot}022\ D^{1{\cdot}5}\, L_p\, P \tag{14}$$

which will serve as a guide to suitable dimensions within the sparkless range. If a fixed ratio of $D : L_p$ could be adopted practically, the formula might be still further simplified, but this is not feasible. It is entirely practical, however, to adopt fixed limits between which $D : L_p$ may vary, thus:

$$L_p \geqq 1{\cdot}5\ \frac{D}{P};$$

$$L_p \leqq 2\,\frac{D}{P}.$$

The accompanying chart has been plotted for the ratios of $D : L_p$ between these limits, advancing in steps of 0·1, and is practically self-explanatory.

The actual diameter adopted will depend largely upon the current density in the armature conductors, the "space factor" of the conductors, and the magnetic density at the roots of the teeth. For belted machines it will suffice to assume tentatively a current density of 2,000 amperes per square inch of conductor cross-section and an apparent flux density of 150,000 to 160,000 maxwells per square inch at the narrowest part of the teeth, making no allowance for fringing. The ratio

$$\frac{\textit{Slot depth}}{\textit{Slot width}} = \frac{s}{h}$$

should not exceed 5 in very small machines, coming down to 4 in armatures of about 18 inches diameter. For larger diameters this ratio may be used also, but it is preferable to reduce it slightly whenever other considerations are favorable. Observing this restriction, the dimensions of a slot may be determined tentatively by allowing 180 mils in depth for insulation and $120 + 10\,n$ mils in width, in addition to the cotton insulation on the conductors, n being the number of conductors side by side in one slot.

Let B_t = Apparent density at teeth roots,
l = Net axial iron length of armature core,
j = Width of one core tooth at the root,
S = Number of slots in the core;

then the aggregate of the tooth widths all around the armature will be

$$S\,j = \frac{\pi\,(D + 2g)\,L_p\,B_p}{l\,B_t}. \tag{15}$$

It is entirely practical to ignore the difference between the circumference of the pole-face circle and that of the armature core, and to assume the net iron measurement to be $0{\cdot}8\,L_p$. On this basis, and the assumptions previously made as to pole-face and maximum tooth densities, the following relation is derived:

$$S\,j = \pi\,K_t\,D^{1{\cdot}1667}, \tag{15-a}$$

the value of K_t being $43{,}000 \div B_t$. The value $0{\cdot}28$ will serve for all ordinary cases.

If one prefers to exercise some discrimination in the matter of the apparent density at the teeth roots and the relation between the net iron length of the armature core l and the axial width L_p of the pole face, and *not* to ignore the difference between the circumference of the pole-face circle and that of the armature core, the relations between the various factors may be very conveniently tabulated by reducing each pair to a ratio. Thus Tables II and II-a give various values for

$$\frac{l}{L_p}, \ \frac{B_t}{B_p} \ \text{and} \ \frac{S j}{D + 2g}$$

within practical limits, the relations between which are identical with those determined by formula 15, π having been eliminated in calculating the values in the tables. These tables, therefore, make it practicable to determine the proper value for any one of the three ratios after having decided upon the value of the other two. Mechanical considerations usually dictate the value of

$$\frac{l}{L_p}$$

and also govern to a considerable extent the value of

$$\frac{S j}{D + 2g},$$

and the application of the trial-and-error method is necessary only to a limited extent in order to obtain satisfactory relations between the three ratios.

Having determined the slot dimensions, the diameter of the core under the slots $(D - 2\ s)$ will be known, and one has at once the formula

$$S = \frac{\pi\,(D - 2\ s - 0{\cdot}28\ D^{1{\cdot}1667})}{h} \qquad (16)$$

for the available number of core slots.

When the size of the machine is such that wire of rectangular cross-section may be used, an appropriate depth of slot may be determined by means of the formula

$$s = 1 + 0{\cdot}125\ \sqrt{D} \qquad (17)$$

and the slot width made to accommodate the thickness of the armature conductor, within the restriction previously set as to the ratio $s:h$. Allowing 90 mils for taping or other insulation on the outside of each group of conductors, the depth of each conductor expressed in mils will be

$$\frac{820 + 125\sqrt{D}}{2} - \text{insulation,}$$

the "insulation" being the total thickness of the cotton insulation on the wire as it is received from the manufacturer. Taking this at 20 mils (10 mils on each side), the depth of a bare conductor, in mils, will be

$$u = 390 + 62{\cdot}5\sqrt{D} \qquad (18)$$

and at 2,000 amperes density, the bare thickness of the conductor, expressed in mils, will be

$$q = \frac{i}{{\cdot}78 + {\cdot}125\sqrt{D}} \qquad (19)$$

from which the width of slot may be derived. Allowing $120 + 30\,n$ mils for insulation,

$$h = n\left(\frac{i}{780 + 125\sqrt{D}} + {\cdot}03\right) + {\cdot}12 \qquad (20)$$

By making up tables or charts of values for s, h, q and u, corresponding to different practical values of D and i, one may choose immediately provisional slot and conductor-dimensions that will require very little if any modification in the final rounding off of each design.

At this point, the criterion for minimum number of commutator segments should be applied, and the ability of the armature to generate the required E.M.F. tested by the application of formula (6) and equation (11), obtaining temporarily a value for λ by using 2·532 as the constant in formula (7) and solving for λ. If the required minimum number of commutator segments cannot be obtained, or is only obtainable by exceeding it absurdly, or if the E.M.F. falls short, the proper diameter may be determined immediately, of course, by the ordinary "rule of three" method, thus:

$$D = \frac{C\,D_1}{C_1};$$

and

$$D = \frac{E^{\frac{2}{3}}\,D_1}{E^{\frac{2}{3}}{}_1};$$

the letters with subscript *1* indicating the values first obtained and the others the required values. Having the diameter, the new length may be readily determined by means either of the chart or of formula (14).

The thickness of a radial carbon brush may be assumed tentatively as

$$b = 3\,g_t\,\frac{D_c}{D} \qquad (21$$

The diameter of the commutator cannot well be expressed in terms of D, since the current and the number of turns per coil must be considered in deducing the mean width of a segment, and the diameter should be kept as small as the size and number of segments will allow. With conductors arranged "two deep" in a slot, the number of segments will be

$$\frac{S\,n}{t} = C,$$

and the value of S cannot always be taken as exactly the number obtained by equation (16) because it must be appropriate to the class of winding used; moreover, the value of n will vary roughly as the E.M.F. of the machine, for a given diameter and output. But a preliminary commutator diameter may be deduced readily enough from the other data that will have been derived at this stage of the procedure, and formula (8) may then be applied, substituting the equivalents of B_p and b given by equations (10) and (21), thus:

$$\frac{g_t\,D^{0\cdot1667}}{i\,c\,t} \geqq 0\cdot00184.$$

If the result is not below the limit set by this formula, the more elaborate criterion afforded by formula (5) may be applied, and the actual proportion of polar embrace, λ, deduced simultaneously, by substituting the values thus far determined and transposing the formula to solve for λ.

The radial depth of the armature core between the slots and the center hole may be determined by means of the equation

$$d = \frac{\lambda\, D^{1\frac{1}{6}}}{P} \tag{22}$$

which has been derived by assuming a magnetic density of slightly less than 68,000 maxwells per square inch, a net iron length, axially, of 0·8 of the axial pole-face length, and the relation between pole-face density and armature diameter that has been carried through all of the calculations.

The cross-sectional area of each magnet core may be ascertained by means of one of the following equations:

For wrought iron,

$$M_w = \frac{1{\cdot}08\, \lambda\, L_p\, D^{1\frac{1}{6}}\, v}{P} \tag{23}$$

For cast-steel,

$$M_s = \frac{1{\cdot}12\, \lambda\, L_p\, D^{1\frac{1}{6}}\, v}{P} \tag{24}$$

For cast-iron,

$$M_i = \frac{2{\cdot}5\, \lambda\, L_p\, D^{1\frac{1}{6}}\, v}{P} \tag{25}$$

in which v is the leakage or dispersion factor. These equations are based on densities of 100,000 maxwells per square inch in wrought iron, 96,000 in steel, and 45,000 in cast-iron. If one wishes to work with other densities, the proper coefficients may be derived thus:

$$\frac{108{,}000}{B_m} = K_m.$$

The leakage factor must, of course, be ascertained from previous experience, or estimated by comparison with some existing machine of similar dimensions and type. It is an utter waste of time to attempt to calculate it.

The length of a shunt field magnet coil parallel with the pole may be approximated by means of the formula

$$L_c = \sqrt{D} \tag{26}$$

from which the length of pole is readily obtainable for simple shunt-wound machines. The series coil of a compound-wound machine need not exceed one-half of the length of the shunt coil, except in the case of heavily over-compounded machines, such as railway generators. A very good guide as to total coil space parallel with the magnet core is

$$L_c' = \sqrt{2\tfrac{1}{2}\, D} \tag{27}$$

for even compounding, or

$$L_c'' = \sqrt{3{\cdot}6\, D} \tag{28}$$

for heavy over-compounding.

The cross-sectional area of the yoke-ring may be determined by means of the formula

$$Y_s = \frac{0{\cdot}6\, \lambda\, L_p\, D^{1\frac{1}{6}}\, v}{P} \tag{29}$$

or

$$Y_i = \frac{1{\cdot}5\, \lambda\, L_p\, D^{1\frac{1}{6}}\, v}{P} \tag{30}$$

the subscripts *s* and *i* indicating cast-steel and cast-iron, as before.

Having completed the preliminary dimensional calculations for a given size of machine, the ampere-turns per pole may be roughly approximated for a shunt-wound machine by means of the formula

$$A\,t = 100\left[\sqrt{D}\left(\frac{1{\cdot}1\,\sqrt{D} + 2}{P} + 1{\cdot}8\,\sqrt{D} + 1\tfrac{1}{2}\right) + 4 - 0{\cdot}6\frac{s}{P}\right] \tag{31}$$

This formula is, of course, based on the assumption of densities and dimensional relations made in the course of this paper, and if those assumptions are carried out, the formula will usually give an excitation value somewhat higher than will be actually required.

In conclusion the author wishes to emphasize the fact that the paper is intended merely to describe the plan of designing that is outlined herein, and not to set up the various assumed values and relations as being in any way superior to those which it may be the practice of other designers to use. It is a simple matter to substitute for the assumed relations used by the author any others that one may prefer, without detriment to the method described, and the latter is submitted in the hope that it may be considered a slight advance over the practice commonly followed in working out direct-current machine designs.

SUMMARY.

Definitions of Symbols :

B_a = Flux density in armature core body.
B_c = Density of commutating magnetic field.
B_d = Density of counter field set up by armature.
B_m = Density of flux in field magnet core.
B_p = Average flux density over pole-face.
B_t = Flux density at roots of armature teeth, assuming no spreading at pole-tips and no flux in armature air spaces.
b = Thickness of a carbon brush set radially.
C = Number of armature coils and commutator segments.
c = Maximum number of segments simultaneously touched by one brush.
D = Outer diameter of armature core.
D_c = Diameter of commutator barrel.
d = Radial depth of armature core between slots and center hole.
E = E.M.F. generated in an armature.
e_c = E.M.F. generated in one coil during commutation.
e_x = Reactance E.M.F. of one coil during commutation.
g = Length of principal air-gap, iron to iron.
g = Average length of air-gap, iron to iron, under an eccentric pole-face.

g_1 = Minimum length of air-gap under extreme pole-tip edges.
h = Width of armature core-slot.
i = Current per armature conductor.
j = Width of an armature core-tooth at the root.
K_c = Constant of commutation criterion.
L_a = Gross axial length of armature core.
l = Net axial measurement of iron in armature core.
L_c = Length of a field magnet coil along the core.
L_c' = Total length of coil space for compound winding.
L_p = Axial length of pole-face.
λ = Average pole-face arc ÷ pole-pitch.
M_i = Cross-section of a cast-iron magnet core.
M_s = Cross-section of a cast-steel magnet core.
M_w = Cross-section of a wrought-iron magnet core.
n = Number of armature conductors side by side in one slot.
P = Number of field magnet poles.
p = Number of paths through armature winding.
q = Width or thickness of a rectangular conductor, bare, in mils.
S = Number of coil-slots in armature core.
s = Depth of each coil-slot.
t = Number of turns per commutator segment (or coil).
u = Depth of a rectangular conductor, bare, in mils.
v = Magnetic leakage factor.
W = Watts.
w = Total number of armature conductors = $2\,t\,C$.
Y_i = Cross-section of a cast-iron magnet yoke.
Y_s = Cross-section of a cast-steel magnet yoke.

Assumed relations:

$$B_a = 68{,}000 —$$

$$B_p = 34{,}380\ D^{\frac{1}{6}}$$

$$B_p\,g = 618.8\ D$$

$$B_t = 150{,}000 \text{ to } 160{,}000$$

$$g = 0\cdot018\ D^{\frac{5}{6}}$$

TABLE I.

Diameter.	$D^{0.1667}$	$D^{0.667}$	$B_p = 34,380\ D^{0.1667}$	$\frac{5000}{D^{0.667}}$	Nearest Rational r. p. m.	Surface Velocity, Ft. per minute.
8	1·414	4·	48,650	1250	1250	2618
9	1·442	4·3267	49,575	1155	1150	2710
10	1·467	4·6416	50,430	1077	1075	2814
11	1·491	4·9461	51,280	1011	1010	2908
12	1·513	5·2415	52,020	954	955	3000
13	1·533	5·5288	52,720	904	900	3063
14	1·553	5·8088	53,390	861	860	3152
15	1·57	6·0822	53,980	822	820	3220
16	1·587	6·3496	54,580	787	785	3288
17	1·604	6·6115	55,140	756	755	3360
18	1·619	6·8683	55,660	728	730	3440
19	1·634	7·1204	56,180	702	700	3482
20	1·648	7·3681	56,660	678	680	3560
21	1·661	7·6117	57,100	657	655	3600
22	1·674	7·8514	57,550	637	635	3657
23	1·686	8·0876	57,980	618	620	3733
24	1·699	8·3203	58,410	601	600	3770
25	1·71	8·5499	58,790	585	585	3830
26	1·721	8·7764	59,170	569	570	3880
27	1·732	9·	59,540	555	555	3923
28	1·742	9·2209	59,890	542	540	3958
29	1·753	9·4391	60,270	530	530	4025
30	1·763	9·6549	60,610	518	520	4083
32	1·782	10·0794	61,270	496	500	4190
34	1·8	10·4951	61,880	476	475	4229
36	1·817	10·9027	62,470	459	460	4335
38	1·834	11·303	63,050	442	440	4377
40	1·849	11·696	63,570	427	425	4450
42	1·864	12·083	64,080	414	415	4563
44	1·879	12·463	64,600	401	400	4607
46	1·893	12·838	65,080	389	390	4697
48	1·906	13·208	65,540	378	380	4775
50	1·919	13·572	65,990	368	370	4843
52	1·932	13·932	66,420	359	360	4900
54	1·944	14·287	66,830	350	350	4947
56	1·956	14·637	67,240	342	340	4984
58	1·967	14·984	67,640	333	330	5010
60	1·978	15·326	68,020	326	325	5105
62	1·989	15·665	68,400	319	320	5194
64	2.	16.	68,760	312	310	5194
66	2·01	16·332	69,100	306	305	5270
68	2·02	16·66	69,445	300	300	5340
70	2·03	16·985	69,790	294	295	5406
72	2·04	17·307	70,130	289	290	5466
74	2·049	17·626	70,460	284	285	5520
76	2·058	17·942	70,750	279	280	5570
78	2·067	18·256	71,060	274	275	5615
80	2·075	18·566	71,360	269	270	5654

$$i\,w\,\lambda = \frac{B_{\mathrm{p}}\,P\,g}{2{\cdot}532}$$

$$l = 0{\cdot}8\,L_{\mathrm{p}}$$

$$q\,u = 500\,i$$

$$r.\,p.\,m. = 5000 \div D^{\frac{2}{3}}$$

$$s = 1 + 0{\cdot}125\,\sqrt{D}$$

NOTE.—All dimensions are expressed in inch measurements, except the size of armature conductors, which is in mils.

TABLE II.

RELATIONS BETWEEN POLEFACE DENSITY AND MAGNETIC PATH IN ROOTS OF ARMATURE TEETH.

Numbers in the body of the table are values of $\frac{Sj}{D + 2g}$.

$\frac{l}{L_{\mathrm{p}}}$	$B_{\mathrm{t}} \div B_{\mathrm{p}}$						
	2	2·1	2·2	2·3	2·4	2·5	2·6
0·80	1·96	1·87	1·78	1·71	1·64	1·57	1·51
0·81	1·94	1·85	1·76	1·69	1·62	1·55	1·49
0·82	1·92	1·82	1·74	1·67	1·60	1·53	1·47
0·83	1·89	1·80	1·72	1·65	1·58	1·51	1·46
0·84	1·87	1·78	1·70	1·63	1·56	1·50	1·44
0·85	1·85	1·76	1·68	1·61	1·54	1·48	1·42
0·86	1·83	1·74	1·66	1·59	1·52	1·46	1·40
0·87	1·81	1·72	1·64	1·57	1·50	1·44	1·39
0.88	1·78	1·70	1·62	1·55	1·49	1·43	1·37
0·89	1·77	1·68	1·60	1·53	1·47	1·41	1·36
0·90	1·75	1·66	1·59	1·52	1·45	1·40	1·34
0·91	1·73	1·64	1·57	1·50	1·44	1·38	1·33
0·92	1·71	1·63	1·55	1·48	1·42	1·37	1·31
0·93	1·69	1·61	1·54	1·47	1·41	1·35	1·30
0·94	1·67	1·59	1·52	1·45	1·39	1·34	1·29
0·95	1·65	1·57	1·50	1·44	1·38	1·32	1·27

TABLE II-a.

RELATIONS BETWEEN POLEFACE DENSITY AND MAGNETIC PATH IN ROOTS OF ARMATURE TEETH.

Numbers in the body of the table are values of $\frac{Sj}{D + 2g}$

$\frac{l}{L_p}$	$B_t \div B_p$						
	2·7	2·8	2·9	3	3·1	3·2	3·3
0·80	1·45	1·40	1·35	1·31	1·27	1·23	1·19
0·81	1·44	1·39	1·34	1·29	1·25	1·21	1·18
0.82	1·42	1·37	1·32	1·28	1·24	1·20	1·16
0·83	1·40	1·35	1·31	1·26	1·22	1·18	1·15
0·84	1·39	1·34	1·29	1·25	1·21	1·17	1·13
0·85	1·37	1·32	1·27	1·23	1·19	1·16	1·12
0·86	1·35	1·30	1·26	1·22	1·18	1·14	1·11
0·87	1·34	1·29	1·25	1.20	1·17	1·13	1·09
0 88	1·32	1·28	1·23	1·19	1·15	1·12	1·08
0 89	1·31	1·26	1.22	1·18	1.14	1·10	1·07
0·90	1·29	1.25	1·20	1.16	1·13	1·09	1·06
0·91	1.28	1.23	1·19	1·15	1·11	1·08	1·05
0·92	1·26	1·22	1·18	1·14	1·10	1·07	1·03
0·93	1·25	1·21	1·16	1·13	1·09	1·06	1·02
0·94	1·24	1·19	1·15	1·11	1·08	1·04	1·01
0·95	1·22	1·18	1·14	1·10	1·07	1·03	1·00

A NEW USE FOR ALUMINUM.

Bernhard, a German experimenter, noting the structure of aluminum, concluded to try it for putting an edge on fine cutting instruments such as surgical knives, razors, etc. To his surprise and pleasure, it acted exactly like a razor hone of the finest quality. Further investigation showed that the metal had other characteristics that made it pre-eminently useful in this direction. When steel is rubbed on it, as for instance, in honing a knife blade, the metal disintegrates, forming an infinitely minute powder of a greasy unctuous feeling that clings to steel with great tenacity, and thus assists in cutting away the surface of the harder metal. So fine is the edge produced that it can in no wise be made finer by the strop, which, used in the ordinary way, merely tends to round the edge. The writer of the paragraph has confirmed most of Bernhard's statements, though he believes he can get an edge with the Ouachita (Hot Springs) hone equally as fine as aluminum gives, and equally as rapidly.—*National Druggist.*

ELECTRICAL SECTION.

Stated Meeting held May 28, 1903.

Static Discharges in Electric Circuits.

BY PERCY H. THOMAS.

INTRODUCTORY.

"Static discharges" in electric circuits supply a very interesting and instructive example of one of the most universal of nature's methods—perhaps the most general of her ways of transferring energy, viz., wave motion. Wave motion plays a very prominent part in nearly every department of physics: heat, light, sound, electricity, dynamics. In its broadest application, wave motion serves to accomplish the transfer of energy. Although in the different branches of physics in connection with which wave motion may be studied, different sorts of forces are involved, and different kinds of effects are produced, yet, at least as regards the wave motion itself, the laws of transmission, form, etc., are the same in all.

In electric circuits, the presence of waves and their form is often extremely difficult to examine on account of troubles in measurement, the great speed with which electrical waves travel, etc. In other departments of physics, however—for example, motion in liquids—the study of waves is comparatively easily accomplished, as their form and progressive changes are visible to the eye. There is a great advantage, therefore, in analyzing electric waves to as far as possible reason by analogy from the more familiar and easily comprehended forms of wave motion, *e. g.*, water waves.

It is an unfortunate fact that, although the formation and progress of waves appear very simple and easily appreciated, yet the mathematical treatment of the subject is very difficult and much involved.

It is the purpose of the present paper to generalize a little on the character of wave motion in general, including the simplest and most important laws involved, and then treat by analogy the effects of waves in electric circuits. It will then be proper to treat the practical bearing of the wave phenomena developed in commercial electric circuits and the available methods of avoiding any injurious effects that might be anticipated from such waves.

Wave Motion in General.—As has already been stated, the general result accomplished by wave motion is the transfer of energy from place to place with more or less change of its form. In the same way as matter, energy may be said to exist; that is, may be considered to be a transferable entity. Energy exists in definite quantity at a definite point and may be transferred from this point to another. Energy, which is found in well-known sources, such as fuel, water-power, radiant energy from the sun, kinetic energy of the solar system, etc., is of commercial use only when existing in an available form at the particular point where useful work is to be done. The transportation of energy is consequently of the greatest importance.

Mathematically speaking, energy or work is developed when motion is produced against a resistance, and the amount of work or energy developed equals the product of the distance of motion by the amount of resistance.

It is evidently possible to transfer energy in two general ways:

(1) By transferring the matter with which energy may be associated, and

(2) By causing the energy to develop a force and causing this force to develop another force at the point to which the energy is to be transferred. The latter method of transfer is the one involved in wave motion.

But there are two ways of energy transfer in the method, involving the transfer of force as force. The first requires a rigid connection between source and receiving point, by which any motion at the source of energy causes a simultaneous and equivalent motion at the receiving point; such, for instance, is the connecting rod of an engine. In the first case the force at the source is at all instants of time equivalent to the force at the receiving point.

In the second case inertia and elasticity are necessarily involved in the transfer of the force; the motion at the source causes motion in its immediate neighborhood, slightly later in time on account of the elasticity assumed, and this motion in turn causes motion slightly further from the source a little later in time and so on until the receiving point is reached, perhaps considerably after the development of the original force. This type of transfer of energy is illustrated by the passage of a wave over a surface of water. Here the original development of force, represented by the elevation of the water at the crest of the wave, evidently passes from one point to another, each point receiving the motion at a slightly later instant of time than the previous point. This second case is, strictly, wave motion, and, as already stated, assumes or requires the presence or the equivalent both of elasticity and inertia in the medium by which the force is transferred from source to receiving point.

Both the latter forms of energy transfer require a continuous medium between the source and the receiving point; in the first case the medium cannot have both elasticity and inertia. In the first case the result at the receiving point is coincident in time with that at the source. In the second, the effect at the source is at a later time. The same transfer of energy may be accomplished by either method through its proper medium.

By both methods the exact rate of development of energy will be reproduced at the receiving point except for an absorption of energy in the medium as the force is transferred through it.

Some examples of the two types of transformation will be interesting. Of the first form, the transfer through a rigid beam like the connecting rod of an engine has been mentioned. Belt, rope or gear transmission is another example. Also the transfer of energy from pump to work piston in a hydraulic pressure apparatus. In electricity, an electric circuit containing a generator and motor, provided the circuit contain no electrostatic capacity, is another example. Here the current flowing produces an exactly equivalent and simultaneous force in the generator and motor. In the second case, as examples, there are the transfer of sound, of light, of heat, of water waves, and static waves in electric circuits containing comparatively large inductance and capacity. In such circuits evidently the first flow of current passes to the capacity near the source of current, and at later periods of time current appears at points more remote from the source and last of all at the receiving point; that is, there is an equivalent force generated both at the generator and at the motor (provided no material loss occurs in the rest of the circuit) but the time at which this force appears at the motor is later than that at which it first appears at the generator. Telephony gives another and very perfect example of electric wave motion.

It will not be necessary to refer again more than casually to the transfer of energy through a rigid medium which represents the ordinary form of commercial transfer of power in an electric circuit.

Nature of Wave Motion.—To develop a little more carefully the nature of wave motion, it will be well to consider another example of energy transfer of the second class, that is through an elastic medium possessing mass, viz., the starting of a long train of heavily loaded cars by a locomotive. In this case the locomotive is the source of energy, the last car may be assumed to be the receiving point; the springs in the draw bars of the cars are the elasticity of the medium, and the weight of the cars its inertia. When the locomotive starts forward the first car starts first, and then as the spring between it and the next extends, the second car starts, extending the second spring and causing the third car in turn to start, etc., the first motion of the locomotive being thus transferred down the train to the end. Here, the time-lag between the development of force at the source and at the receiving point is very evident. It is evident, also, that this lag is due to the combination of the inertia and elasticity in the train. If the locomotive be reversed when the train is all in motion, the first car, as before, will receive backward motion first, the second, through the first spring, a little later, and so on to the end of the train, the last car being the last to feel the reverse impulse. This starting impulse which passes from the front to the rear of the train is really a wave and is transferred through to the medium in exactly the same way that a sound is transferred through a tube. It must be noted that the first impulse of the locomotive started the first car and this the second, and so on, and that the original impulse would pass the length of the train to the end whether the locomotive, after delivering its push, stopped immediately or continued in its motion. If the second impulse of the locomotive was to stop then after delivering the first starting impulse to the second car, the first car would be stopped by the locomotive, it in its turn would stop the second and so on, the second impulse following the first down the train to the end. If the second impulse of the locomotive had been another impulse forward, the first car would receive a second impulse forward, followed by the second car, etc., and the last car would receive the two impulses as separately as the first car or the second. The same length of time would elapse between the first and second impulses at the last car as at the locomotive.

If all the cars be of the same weight and the springs of the same strength, all waves of motion produced by the locomotive will pass down the train with the same velocity. This fact is generally true in wave transfer. All waves tend to pass at a uniform rate through the mediums which have the same elasticity and inertia characteristics. Mathematically speaking, the velocity of motion of the wave forward is proportional, inversely, to the square root of the product of the elasticity and the inertia. In cases where there is a loss of energy as the wave passes through the medium, a certain slight alteration in the velocity results.

Returning to the example of the train; if we assume that a locomotive starts forward and continues its motion for some time until the whole train has attained the same velocity, and then stops and runs backward for the same distance, and repeats this cycle again, we have an alternating force, so to speak, and waves alternating in direction are sent down the train, but each forward wave is completed before a negative wave begins, and vice versa. Suppose, on the other hand, however, that the locomotive starts forward and then backward rapidly so that the backward movement of the locomotive is accomplished before the previous forward movement has reached the rear of the train; we then still have the alternating force at the locomotive and a constant series of waves passing down the train, some positive and some negative. That is, cars in some parts of the train are moving forward and others moving backward all at the same instant.

In the latter case the distance along the train between the two nearest cars which are moving forward at the same time is called the wave length. It is the distance which the original motion will travel during the time required for the locomotive to have completed one cycle of movements and to begin repeating this cycle. Wave length in water waves is the distance between the crests of two adjacent waves, which is, of course, the same as the distance between the troughs. The wave length evidently depends upon two factors: (1) the speed with which the wave travels in the medium, and (2) the time required for the exciting force to complete a cycle movement. The term wave length is used chiefly where the exciting source goes through regular repetitions of the cyclic motion.

In the first case above in which the locomotive required a long time for completing a cycle of motion (that is going forward and returning) the effect on the rear car was *practically*, though not exactly, the same as though the train had been perfectly rigid and the transfer of energy had been made after the same fashion as that of a connecting rod. In the second case, however, in which the alternations of motion of the locomotive forward and backward were so rapid that several occurred before the end of the train was affected, the motion of the rear car, though of the same nature exactly as that of the locomotive, was yet very different as regards the time at which such motion occurred relatively to the time of the exciting motion in the locomotive; that is, there is a great time lag between the source and the receiving point. This time lag is of more importance in electric circuits than in the case cited.

Recapitulation.—When a force is produced at a source of energy at one end of a proposed line of transmission for this energy, a wave of force is started which passes along the line at a constant, definite rate (which is inversely proportional to the square root of the product of the elasticity and the inertia of the medium in which the motion exists) until the end of the line is reached. If the original force be alternating in its nature, a succession of waves of opposite directions will follow one another to the receiving end, keeping a constant distance apart, equal to the space traversed by a wave during the time of one cycle of the source. If this cycle be slow in comparison with the time required for a wave to traverse the whole line, the effect at the receiving end will be practically the same as though the force were directly applied at this point. This action is closely analagous to the transmission of power in ordinary commercial circuits in which there is only a comparatively small capacity connected with the system which delays the current only slightly as it starts up, and which allows the action both at the generator and motor end to be substantially simultaneous. In the case where the cycles of the source are very quick in comparison with the time required for the way to pass the length of the line, however, there are a number of waves passing down the line at the same time, and the shortest distance between two similar waves is called the wave length. The wave length depends upon the velocity of the wave in the medium and on the frequency of the alternations of the source. In any given circuit different wave lengths can be obtained by applying alternating forces of different frequency. In commercial circuits since the velocity of the transmission of electric waves in straight wires in the air is approximately the velocity of light, the only common method by which sufficiently rapid alternations of applied force can be obtained to cause several waves in a line at one time is by a static discharge; that is, a sudden changing of the potential of a portion of the line caused by allowing it to discharge over an air-gap or its equivalent.

Laws of Wave Motion.—As supplementary to this description of the nature of wave motion, the simplest laws governing such motion will be discussed. After a general treatment of these laws their application to commercial electric circuits will be considered.

Suppose, in the first place, the source of energy is in the center of a large homogeneous medium capable of transmitting the wave in any direction, for instance; a tuning fork in the center of a large room. Waves will be sent out in all directions with each motion of the tuning fork. It is evident that as each wave passes farther and farther from the source, since its velocity is the same, a larger and larger quantity of medium must be affected. This means, evidently, that the intensity of the wave at any particular point of the medium gets less and less as it passes farther and farther from the source. Since the amount of the medium affected at any distance from the source varies as the square of this distance, the intensity of the wave varies inversely as the square of its distance from the source. This is the well-known inverse square law governing the intensity of sound, light, heat and of any form of energy which can be radiated from a point. This is not the case involved in electric circuits, however, and will not be further discussed.

If, instead of being placed in a medium in which they can pass in all directions, the waves are confined to one plane, as the waves on the surface of water, waves will again be transmitted in all directions in this plane and will again diminish in intensity, since larger and larger amounts of the medium are involved as the waves get further from the source, but in this case the diminution is only inversely as the first power of the distance, since the amount of the medium excited by the wave in a given time increases only in this ratio.

Suppose again, however, that the medium be confined to a tube, a speaking tube, as for sound, and be allowed to pass in one direction only. In this case, since waves do not excite any larger portion of the medium at a distance from the source than nearby, there is no diminution of intensity due to the spreading out of the original wave as it proceeds farther and farther from the source. The electric circuit is analogous to the case of the tube-shaped medium, therefore this form only, called linear waves, will be discussed. There may, however, be a certain loss of energy due to resistance to motion in the medium, or other supplementary waste of energy which is not characteristic of wave motion in a perfect medium. This will tend, even with linear waves, to lessen the energy of the wave and change its form somewhat. The most important laws governing linear waves will be discussed under their appropriate headings.

Velocity.—It has already been stated that the velocity is inversely proportional to the square root of the elasticity times the inertia, and is slightly altered by any waste of energy in the transmission of the wave.

Wave Form.—The general form and amount of energy in the wave are determined at the instant of its creation at the source, and in a perfect medium would remain unchanged through all transmission. Energy losses, however, somewhat modify the form of the wave as well as altering its velocity. Once a wave has left the source, no subsequent action of the source can modify it directly.

Reflection.—When a wave reaches the end of a conducting medium, and can go no farther, it is reflected backward without change except of direction, and returns back through the medium toward the source at the same velocity. The effect is exactly the same as though the original wave went on to infinity and a new wave were started exactly like the first at the reflecting point, at each instant exactly similar to the outgoing wave. Thus, it will be seen at the reflecting point for the instant of reflection there will be twice the intensity of the original wave. If this be an electric wave, there will be twice the potential at this instant. The increased potential exists only during the time of reflection.

If, instead of meeting an obstacle in its path at the end of the line, the wave meets a point where all of its energy can be absorbed, such as a short circuit or a large condenser in an electric circuit or an open mouth of a trough of water, the wave will still be reflected, but this time with a reversal of the direction of this intensity; that is to say, a wave will start backward from the reflecting point as in the case of meeting the obstacle as above, but will be of a negative sign, a lowering of potential in the electric circuit instead of a raising potential. This will pass on toward the source as before.

In acoustics the former case represents a closed organ pipe in which the sound is reflected at the closed end and returns as a condensation toward the lip of the pipe. The second case illustrates the open organ pipe in which a rarefaction is sent back toward the lip by reflection.

If the reflected wave reach the generator it will there be reflected into the line again with reversed sign without altering any other waves which the generator may be sending out.

Nodes and Loops.—It is evident from the paragraph above that if a continuous series of alternating waves be produced by the source and these be reflected from the receiving end, whether it be an obstacle (an open wire), or short circuit, the returning reflected waves and the new series of outgoing waves will pass one another. The resultant effect will be the sum of the two; that is, where a wave returning meets a wave going out, there will be a wave of double height for the moment. Where a wave returning meets a wave going out of the opposite sign, however, these two will neutralize and there will be no effect at that particular point. A little consideration will show that the returning positive wave will meet outgoing positive waves always at the same points and that the returning positives will meet the outgoing negatives, and vice versa, always at the same points. Consequently, the points of extra high intensity and points of

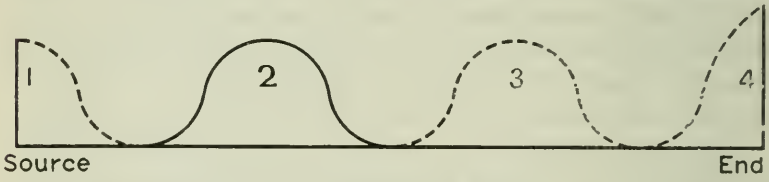

FIG. 1.—Passage of wave.

zero intensity are fixed, the natural result being that a series of high and low points are kept reappearing and disappearing as the waves pass out and back, but which are stationary in location. These are called nodes and loops, and the highest points are double the intensity of the individual waves sent out. The outgoing waves and the nodes and loops are illustrated in *Figs. 1* and *2*. This double voltage is really the same phenomenon as the double voltage produced by reflection at the closed end of the wire or tube.

Resonance.—When a returning wave reaches the generator it is reflected into the line again with change of sign as

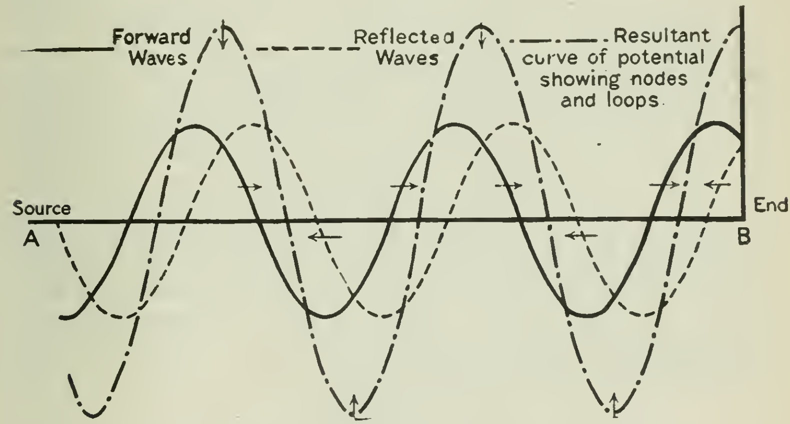

FIG. 2.—Nodes and loops in a long line or cable.

already described. If at the same time the generator be sending out a wave of the same sign as the reflected wave, a wave of double intensity will proceed to the end of the line, be reflected and return to the generator, where it will again be reflected with reversed sign, and the new wave which will just be leaving the generator, with the double wave just reflected by the generator, will form a wave of triple magnitude. This will return to the source as before, and step by step intense waves will be built up which will theoretically reach an infinite value, provided no loss of energy occurs; but such losses do occur in all cases, which fact allows the intensity of the wave to build up only to such a point that this energy loss equals the energy supplied by each additional wave. This phenomena is perfectly analagous to resonance and is, in fact, a more general case of resonance. Ordinarily it is considered that resonance occurs when inductance and capacity occur in a circuit in such proportions that the condenser discharging through the inductance has its charge oscillate from one side to the other of the condenser as a pendulum oscillates and in addition there be applied in the oscillating circuit an alternating electromotive force, or in the case of the pendulum an alternating force, which has exactly such a frequency of alternation that the impulse of the electromotive force, or the force, as the case may be, is just right to increase the energy of the electric discharge or the amplitude of the pendulum swing. An example of ordinary resonance in acoustics is the exciting of one tuning fork by another tuned to exactly the same note. The corresponding example of the other type of resonance (produced by wave motion and reflection) is the resonant tube or organ pipe where the particular tones produced at the mouth which are of the right frequency have their intensity greatly increased by the waves reflected from the end of the pipe. Different length pipes evidently require different times for the passage of waves from one end to the other and back respond to the different frequencies.

[*To be concluded.*]

Notes and Comments.

PRODUCTION OF ASPHALTUM AND BITUMINOUS ROCK IN 1902.

The production of asphaltum and bituminous rock in 1902, according to the report of Dr. Joseph Struthers to the United States Geological Survey, now in press, showed a large increase over that of 1901, amounting in quantity to 36,525 short tons and in value to $122,259, the figures for the two years being, respectively, 99,659 short tons ($677,594) and 63,134 short tons ($555,335). The relatively smaller increase in value as compared with quantity was due to the very large proportion of bituminous sandstone produced.

The production of hard and refined asphaltum increased from 19.316 short tons in 1901 to 22,321 short tons in 1902. The production of liquid asphaltum, all of which was derived from California, decreased from 2,600 short tons in

1901 to 1,605 short tons in 1902. The quantity of asphaltum produced in the refining of crude oil during 1902 amounted to 16,027 short tons.

The imports in 1902 amounted to 153,093 long tons ($492,604), as compared with 138,833 long tons ($553,473) in 1901.

The report contains a brief abstract of the production of asphaltum in Cuba in 1901.

PRODUCTION OF BORAX IN 1902.

The known deposits of borax in the United States, according to the report of Dr. Joseph Struthers to the United States Geological Survey, are in California, Nevada and Oregon, and the chief producer of borax and boric acid in this country is the Pacific Coast Borax Company, which owns the plant at Daggett, San Bernardino County, Cal., where the colemanite (calcium borate) is bedded in deposits from 5 to 30 feet thick. This company acquired much additional property during 1902 in the Death Valley region.

It has not been practicable to separate the total output of borax salts during 1902 into the crude and the refined product; the reported returns, however, give an aggregate production of refined borax and boric acid amounting to 17,202 short tons, valued at $2,434,999, of which 862 short tons, valued at $155,000, were stated to be boric acid. The production during 1901 was 17,887 short tons of crude borax, valued at $314,811, and 5,344 short tons of refined borax, valued at $697,307, a total value of $1,012,118.

The largest refinery in the country is at Bayonne, N. J., to which the pulverized colemanite is shipped in sacks from California.

The borax deposits of California have been fully described by Mr. M. R. Campbell in Bulletin No. 200 of the United States Geological Survey (1902), and by Mr. Gilbert E. Bailey in Bulletin No. 24 of the California State Mining Bureau (1902).

CLAYS OF THE UNITED STATES EAST OF THE MISSISSIPPI RIVER.

The United States Geological Survey is about to publish, as Professional Paper No. 11, "The Clays of the United States East of the Mississippi River," by Dr. Heinrich Ries, a paper that has been looked for with interest by a large number of persons, particularly by those engaged in some form of the clay industry.

Dr. Ries discusses briefly the origin, physical and chemical properties, methods of mining, purification, commercial value, and uses of clay, and the geologic distribution of clays east of the Mississippi according to their rock derivation; and then he takes up the distribution of clays by kinds, and the description of clay deposits by States. He concludes with a summary of the clay-working industry east of the Mississippi, touching in turn and by States on the manufacture of common brick, pressed brick, fire-proofing, roofing tiles, terra cotta, enameled brick, floor tiles, glazed tiles, vitrified brick, drain tile, sewer pipe, fire brick, and pottery.

The largest brick-making region in the country is the Hudson River Valley, in New York State, where nearly a billion brick are made annually. Pennsylvania leads in the production of pressed brick. Most of the terra cotta comes from New York, New Jersey, and Illinois. Although West Virginia was the cradle of the paving-brick industry, Ohio now leads in the production of vitrified brick. Ohio, Illinois, Indiana, and Michigan are the most important producers of drain tile, and Ohio is the main producer also of sewer pipe. Pennsylvania produced over $4,500,000 worth of fire brick, about one-half the total production, in both 1900 and 1901. Ohio, New Jersey, and Pennsylvania, in the order named, are the greatest producers of pottery, East Liverpool, O., and Trenton, N. J., being the chief centers of production.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, October 21, 1903.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 21, 1903.

Vice-President JOHN BIRKINBINE in the chair.

Present, 162 members and visitors.

Additions to membership since last meeting, 14.

Mr. J. B. Fontaine, Jr., presented a model of a working-beam engine made by the late Mr. Henry Cartwright, a former vice-president of the Institute. A vote of thanks was tendered to the donor.

Mr. John W. Hill, Chief Engineer, Department of Public Works, gave a description of the Belmont Filtration Plant now in course of construction by the city of Philadelphia. Mr. Hill's communication was profusely illustrated by means of lantern photographs. The president extended the thanks of the meeting to the speaker for his able and exhaustive contribution to the subject.

Adjourned, WM. H. WAHL,
Secretary.

Committee on Science and the Arts.

[*Abstract of proceedings of the stated meeting held Wednesday, Oct. 7, 1903.*]

MR. CHAS. E. RONALDSON in the chair.

The following reports were adopted:

(No. 2202.) *Exposure Scale for Timing Negatives.*—Edward Wagner-Smith, Philadelphia. (An advisory report.)

(No. 2237.) *Tube Expander.*—Chas. V. Burton, London, England. (An advisory report.)

The following reports passed first reading:

(No. 2164.) *Steam Generator.*—John C. Parker, San Francisco, Cal.

(No. 2303.) *Measuring Device.*—Edgar Hill, Philadelphia.

These were held under advisement.

Protests against reports were received in the following cases:

(No. 2268.) Rulon's *Electric Battery.*

(No. 2272.) Eberhardt's *Radial Gang Cutter.*

These were referred to sub-committees. W.

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

The School City.

[*The report of the Franklin Institute, through its Committee on Science and the Arts, on the system of civic education devised by Wilson L. Gill, of New Paltz, N. Y.*

Sub-Committee: Louis E. Levy, chairman; Samuel P. Sadtler, Lewis M. Haupt, Martin I. Wilbert, Harry F. Keller, Raimundo Cabréra.]

[No. 2293.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the system of civic education originated by Mr. Wilson L. Gill, of New Paltz, N. Y., and known as the School City, reports as follows:

The essential feature of this invention, for as such, in the strict sense of the term, it is to be regarded, consists of a novel method of school organization devised for the purpose of perfecting the existing general school system by the addition of a method of teaching social science objectively; in other words, of imparting a knowledge of the mechanism of government by means of object lessons, and in such manner as to bring this fundamental but complicated subject-matter within the comprehension of school children.

The correlation of the individual and the community has naturally been a matter of immediate interest from the beginnings of society, and the adjustment of these relations, the function of government, has likewise always been a matter of paramount importance. In the processes of government the individual was long held as the subject rather than the object of its functions, the people being regarded as belonging to the governing power instead of the power belonging to the people. In these cruder stages of social evolution, civic relations have always been viewed in the light of military or religious considerations, and regulated from the standpoint of monarchic or hierarchic interests. Thus the duty of the individual to the community was commonly regarded among the Greeks and Romans from the military point of view, in the mediæval systems from the religious standpoint; and later, in the Renaissance period, from both combined, or rather most frequently from both in opposition. Throughout all these stages the rights of the individual were scarcely considered as existing at all, and at best were but dimly recognized as important, until finally, after centuries of groping, the American Revolution formulated these rights into a modern creed and the French Revolution destroyed the older ones.

From that point to the present the advance in this direction, as in all other avenues of progress, has been very marked. With a growing perception of the true relations of the people and the government, the study of these relations has developed into a science, based, as all true science must be, on natural predicates and proceeding logically in the light of experience and facts. It was yet long, however, before the science of government was disentangled from political history, and longer yet before it was definitely recognized as apart from the science of political economy, with which it had been relegated to the purview of colleges, universities and other seats of higher learning. It is only within the present generation that the distinction has been clearly drawn and only within recent years that the science of Civics, the mechanism of government, has been appreciated as a proper subject of study in our common schools.

The modern scientific theory of civic organization, and that on which our system is based, is that of popular self-government, but this ideal is as yet but imperfectly realized in practice. The theories formulated in our constitutions and our charters are scientifically correct and fully practicable, but the actual results fall far below the theoretical requirement. This is most manifest in the workings of our minor governmental organizations, it being true in this domain, as in that of mechanics, that the theoretical result is most apt to be approximated in the larger units. Thus the theory of government of the people by the people is most nearly realized in the workings of our general system, both as regards its practical efficiency and its ethical qualities as well. It is less so in the case of the component units, particularly the smaller ones, where both the practical and moral aspects of the subject are often equally unfavorable. The low efficiency of our township governments is but too frequently evinced in defective school facilities, still more defective roads and in other manifestations of civic torpor, while our municipal governments, with larger and wealthier constituencies, are proportionately scarcely more efficient than the former and but too often disproportionately corrupt.

It behooves us to study earnestly the cause of these conditions. The soundness of the theory on which our system of government proceeds cannot be logically questioned. Its fundamental principle, once so memorably summarized as "a government of the people, for the people and by the people," is clearly in accordance with the nature of things and with the normal condition of human nature. It works out satisfactorily in many respects and it fails, where it does fail, not through any defect in the principle, but through its defective application. The shortcoming lies not in our civic organization, not in our mechanism of government, but in the manner of its use. Applying here, as especially pertinent, a current figure of speech, it is not in the guns, but in the men behind the guns, that the failure of the combination lies. It is in our educational system that the shortcoming is to be found, and not so much in lack of education as in the lack of such training as will make it practicably effective. The theory of civics is, indeed, taught in our schools, but the art of civics remains unappreciated or at best but vaguely understood. An understanding of any practical science can only be gained experimentally and the science of government is no exception to this rule. It is being taught in formulas, but not in practical application, and the result remains such as is obtained when physics and chemistry are taught in like manner. For these latter our high schools have laboratories for practical demonstration, and even the lower grades utilize physical apparatus for the same purpose. With higher efficiency in all directions constantly demanded by the growing exigencies of our day, and with the requirements of citizenship constantly growing under the increasing complexity of social affairs, there is need that special effort be given to fulfil these requirements. We have established courses of manual training, of industrial art, of technology generally in order to impart to the rising generation a knowledge of the applied sciences; it appears to be time, in view of all the conditions, that the teaching of the theories of civics be supplemented with lessons in the practical art.

It has long been recognized by leaders in educational progress that object lessons are indispensable in the teaching of objective facts. As early as the middle of the seventeenth century the Moravian bishop Comenius, working in various countries of Europe, urged as a basic principle of education that the teaching of words and the things they signify must go hand in hand, and in England Milton took up the same idea and made it a theme of the "Tractate of Education," which he wrote and published. The fundamental idea of the school system organized by Comenius for the kingdom of Sweden, 1642–46, was to take full advantage of the innate tendency of children to exercise their faculties and to utilize this natural desire for activity in the process of their education. He preceded his contemporary, Milton, in pointing out that antagonisms between pupils and their teachers became reflected in a repugnance to learning, and he sought in every way to remove this obstacle. His life-long labors for the improvement of educational methods might have had other than the sporadic results that were obtained but for the turbulencies of the Thirty Years' War and the religious animosities growing out of it, and it waited another hundred years until Rousseau, in 1762, gave Europe another impulse to educational reform. He, too, like Comenius, looked to the natural processes of life for guidance in the education of the child, and, more fortunate than his predecessor, he found an apt psychological moment for the propagation of his ideas. His doctrines profoundly affected the educational direction of the rising generation of his day, but they had scarcely time enough to do more than help to usher in the French Revolution when in common with many other outgrowths of the times they were suffused in that eruption. But Rousseau's influence had been enough to leave its impress on the neighboring countries of Switzerland and Germany at least, and eventually through these channels on the modern educational system generally. It was his work that influenced Pestalozzi, who took up Rousseau's ideas in Switzerland and there gave them a more practical and realistic turn. His fundamental idea was the combination of training with instruction, and his methods consisted in directing the faculties of observation and perception with the view to developing judgment as well as understanding. Pestalozzi's activity was continued into the early decades of the nineteenth century, and his efforts influenced largely the tendencies to improvement in school methods which have proceeded since his time. It was under his tuition that Froebel crystallized his own original conceptions of the education of young children. He perceived that Pestalozzi's idea that the child belongs to the family and Fichte's idea that it belongs to the community were each but half-truths and that both concepts, like all half-truths, were apt to be mischievous and misleading. The child belongs both to the home and to society; both have an abiding interest in its present and future welfare. Froebel's guiding thought was that the process of education through which the child gradually learns to take its place in the family circle, should be continued in school, so that it may likewise learn to take its place in the community. His experience as a soldier had impressed him with a realizing sense of the fact that the individual is but a functionating part of the social organism, and that a complete development of both required of the individual the full and proper performance of his functions. Out of these conceptions grew his doctrine of "Selbstthätigkeit," spontaneous activity, from which he deduced the corollary that man learns truly only through voluntary action. He felt the importance of so training the natural impulses of the child that it should spontaneously act in harmony with the general well-being, and to that end he sought to influence the child from its earliest years in such a manner as to imbue it with a sense of its responsibility. He found a way to realize his ideas in the Kindergarten, where the child is trained to pursue its natural home life, play, in common with numerous of its fellows, under the discipline of communal proceeding, and where it is taught the rudiments of manual skill.

As usual with all innovation on accustomed methods, Froebel's system of child culture encountered opposition on every hand, including even the ministry of public education of the kingdom of Prussia, where it was not permitted until long after it had been gladly welcomed and had become deeply rooted in Switzerland, England and the United States. Froebel's system has been greatly developed since his death in 1852, mainly, however, in the direction of manual training. The complex industrial system which has grown up within that time has inevitably caused this trend, but the increasing complexity of modern society which has been incidental to that growth, especially in large centers of population, has come to demand that the sociological feature of the Kindergarten be now developed, as the industrial feature has been already. The new conditions of society impose new duties and larger responsibilities on its individual members, and the demand that has grown with this condition is for such addition to our educational facilities as will afford the means for training the rising generation in the performance of these duties. This demand has been met by the School City System worked out by Mr.

Gill, which manifestly offers practical means to the end in view, and which, in the light of several years' experience and from the concurrent testimony of numerous competent observers, is fully adequate for its purpose.

The School City System consists in organizing each school into a self-governing community, the members of which act as enfranchised citizens and constitute a miniature city government through officials elected from among themselves. The organization is begun by convening the pupils in a general or town meeting, to which the principal and teachers accord a charter, incorporating the school as a municipality and giving each pupil the status of an elector. This, in itself, affords a striking object lesson in this fundamental procedure of city government. Each class in the school is then organized into a city ward, which elects one or more delegates to a nominating convention, through which candidates for the various general offices, such as Mayor, Sheriff, Judges, etc., are proposed for the suffrages of the citizen pupils, who thereupon determine the election by majority vote. Each ward, furthermore, elects two or more members to represent it in the city councils. The Mayor nominates his executive assistants subject to the approval of the councils, including the heads of the Health, Fire and Police departments, and each of these officials in turn selects his assistants, subject to the Mayor's approval, the police force being made up of several pupils from each class.

The disciplinary regulations of the school are formulated by the city councils in due conformity with the requirements of the occasion and subject, of course, to the final revision of the school principal. These regulations are designed to cover all the various phases of school life apart from the courses of study and the school curriculum generally, and include such subjects as cleanliness, sanitation, orderliness and general decorum, all of which usually requires the constant attention of the teachers, sometimes to such an extent as to materially interfere with, if not actually to reduce the efficiency of their tutelage. Under this new system of discipline the work is relieved of much of its burden, the school regulations being thus in charge of the pupils themselves. It lies in the very nature of things that the children at once realize their individual responsibility, and knowing instinctively, as well as from their experience, the necessity for these regulations, they feel an individual interest in seeing them properly observed. Infractions of the regulations are first called to the attention of delinquents by the police force appointed for the purpose, and if not corrected, the culprits are called before the judges, who try the case, weigh the evidence and fix the penalty, the greatest punishment being deprivation of the rights of citizenship, which relegates the offender to the jurisdiction of the principal and teachers, and bars him from the general organization. The jury system can be added as occasion requires, and is practicably applicable in the more advanced classes of older children. The term of the various offices is made short, especially those of the police department, so as to give all the pupils, as far as possible, an opportunity of gaining the experience of exercising them. The children thus learn the methods of government and obtain a realizing sense of its necessity, carrying away with them a permanent consciousness of their individual part and interest in its composition.

Under the customary system of school government, trespassers are regarded as culpable only when found out. The regulations being held as restrictions of liberty, infractions thereon are apt to be considered as nobody's business but the teacher's; any objections from a pupil are regarded as hostility, and any information concerning it is tabooed as "tattling." Under this system the child is apt to grow up with a sub-conscious sense of opposition to law and order, and at best with a feeling of indifference to it. This attitude of apathy continues in after-life and is prone to remain unaffected except when quickened by the touch of some immediate personal interest. The result is such as is frequently apparent in contemporary civic life, where large numbers of citizens remain indifferent to many civic affairs of general importance and leave these to be determined by others who have or seek in these affairs some individual or private gain. The apathy and indifference from which these conditions arise are traceable in large measure to the unfamiliarity of the masses of the people with the machinery of government, and this ignorance the School City system is calculated to remove.

The School City method of teaching civics calls for the fullest recognition by all official Boards of Education, and it is almost self-evident that the system needs only to be carried out with a due measure of sympathetic encouragement and tactful supervision by the school principal and his or her assistants, to become an agency of far-reaching benefit in the sociological education of children. It furnishes a continuous object lesson in the science of government, inculcating at once the responsibilities and the duties of citizenship, and the ethical requirements of civic life. The pupils, instead of becoming imbued with a sense of antagonism to what is to them an arbitrary government, imposed by superior force, learn through their School City the value of the franchise and the importance of exercising it. Through ceasing to be subject to the exercise of power except as it expresses their own, they obtain a consciousness of personal dignity which is of utmost value in the upbuilding of character and which makes strongly for that ultimate aim of all true education, proper conduct in daily life.

It is but natural that the necessity for supplementing the tuition of common schools with lessons in the science and art of government, and also the invention born of that necessity, resulted first in our American democracy, where sovereign power is shared by every citizen. The need of this has been felt with increasing force for some time past. In 1888, the Patriotic League was organized under the presidency of Mr. Gill, with the co-operation of some of our leading publicists, for the purpose of fostering a healthier and more intelligent citizenship throughout the country, and his efforts in this direction gradually led to the development in 1896 of the School City system as it is now in use. While the first experiments with the School City method were being made by the inventor in New York City in 1896–97 the League of Good Citizenship, a branch of the Civic Club of Philadelphia, was promoting a similar movement here. This took the form of branches of the League, organized in several of our Philadelphia schools, each branch subdivided into companies at the discretion of the principal. The companies meet once a month, under direction of a teacher, the meetings being designed to inculcate a proper regard for the regulations of the school and for the ordinances of the city. The system is under the charge of a committee of women and has been fruitful of good results.

There have not been wanting various other suggestions and experiments in this direction, such as the George Junior Republic, where a boys' reform school is organized as a self-governing community, and different modifications of the same idea in other institutions; but no comprehensive system of moral and civic training, adapted for use in common schools, preceded the introduction of the Gill School City. After the initial experiments in 1897, in several schools in New York, the system was introduced by discerning school principals in various cities of the country, and in 1898, by authority of the Board of Education of Philadelphia, the Hollingsworth Combined School in this city was organized on this plan, with the assistance of Mr. Gill. The system was at that time to have been extended to other of our local schools, but this was deferred through the originator being called by the Federal government to supervise the engrafting of his method on the school system of Cuba, then being organized under the military governorship of General Leonard Wood. The latter had become cognizant of the workings of the school city and deemed it of such importance for the educational system of the nascent Cuban republic that he determined on its adoption, and secured the services of Mr. Gill for the purpose. The School City was accordingly made part of the educational system organized in Cuba, and, as attested by some of its foremost citizens and leading educators, has quickly proven its value and efficiency. Latterly, since Mr. Gill's return from Cuba, at the request of the Secretary of War, to introduce his system in the Philippines, and before his prospective departure, he has undertaken to complete in this city the work which was interrupted in 1898, and has now organized school cities in more than twenty of our public schools, to the eminent satisfaction of both teachers and pupils.

In the State Normal School at New Paltz, N. Y., where the School City has been in operation since early in 1900, the system has been developed to include the practice of various advanced principles of popular government, such as proportional representation, the initiative and the referendum, and has, moreover, been amplified into a school state, composed of a number of separate schools, thus putting in practice the processes of state and federal government. The possibilities of the system as a school of practice in the science and art of civic organization generally will be obvious without further detail.

The School City has been earnestly taken up in Great Britain, as is apparent from a recent work on Education by L. W. Williams, of Glasgow; it is being strongly urged for adoption in the public schools of France, and is being introduced into Mexico. Wherever the principles of parliamentary government hold sway, and especially where they are established on the foundation of popular sovereignty, as in our country, the necessity of training the electorate in the art of government is felt as a crying need of the present day, and as an imperative necessity of the immediate future. If the material well-being which has resulted from the gains of science and the arts is to be free from the dangers of a growth of civic apathy and the decay of civic virtue, and if the further progress of industrial development is not to be hampered and the normal evolution of our political and social system is not to be hindered and perhaps arrested by civic incapacity, then some adequate means of civic education must be applied. Hitherto our only constant reliance in this direction has been the public press, but this agency must as yet make its appeal to a body of citizens for the mass of which the art of government is but a vague, and at best, largely an academic proposition. Through the School City this and all other existing agencies of civic education will be effectively reinforced by a practical training of the rising generation in the duties of civic life, imparted in the schools and during the years when culture and training have their most lasting effect.

In recognition of the great value and importance of the Gill School City system and of its usefulness as practically demonstrated, the Franklin Institute herewith awards to the originator, Wilson L. Gill, the Elliott Cresson Gold Medal and Diploma.

Attest: WM. H. WAHL,
Secretary.

PHILADELPHIA, June 1, 1903.

SOURCES OF RUBBER SUPPLY.

The Department of Agriculture has issued an interesting bulletin on rubber culture and production in the Central American States and the dependencies. The publication is the work of O. F. Cook, botanist in charge of tropical agriculture, who has made an exhaustive study of rubber culture in every field of production. Its importance appears from the fact that rubber is the third of the large imports from the tropics, sugar and coffee being the first and second respectively. The average value of the yearly importation of rubber is $28,000,000. These studies are directed primarily to the question whether rubber culture is promising for Porto Rico and the Philippines, and the principal fact established in this report, namely, that a continuously humid climate is neither essential nor even desirable for rubber culture, promises well for the extension of this industry to the tropical islands of the United States.

It is now accepted that rubber can be cultivated and that the supply from wild growths cannot be relied on for a sufficient amount from year to year. At the same time it has hardly been shown that cultivation is safe and profitable, and the whole industry may be said to be still in the experimental stage. It has been demonstrated that the Para tree may be cultivated interchangeably with the Castilla in Central America and Porto Rico, and is producing handsome results in the Malay Peninsula, Ceylon and Borneo. The variety of soils, exposures, altitudes and climates where Castilla will be successful have been found to embrace widely separated sources of supply. Mr. Cook commends rubber culture in the Philippines in view of what has been learned about Castilla.

Studies of Castilla in Mexico have resulted in a favorable opinion regarding the prospects of Castilla in Porto Rico since it is believed that the requirement of continuous heat and humidity has been over-stated. Mr. Cook says there are toward the southwest corner of the island many places where the climatic conditions are not unsuited for Castilla and where experimental plantings should be made.—*Electrical World.*

THE FRANKLIN INSTITUTE.

Read at the Stated Meeting, held Monday, November 18, 1903.

Decorated Stove Plate, 1764, from West of the Susquehanna.

By Prof. Charles F. Himes, Ph.D.

In the very interesting and valuable historical contribution of Professor Henry Mercer on "The Decorated Stove Plates of the Pennsylvania Germans," published by the Bucks County Historical Society, all the half-tone illustrations, twenty-three in number, are from castings made east of the Susquehanna. It is an interesting question not only when and where such castings were first made west of the Susquehanna, but also how they might be related in design and craftsmanship to those in the eastern part of the State. In the "Postscript" to the original paper Professor Mercer alludes very briefly, without illustration, to a plate which has an interesting bearing on this question. What seems to be a duplicate of the one alluded to has been added, recently, to the local historical collection at Carlisle, Pa.,* taken from the back of a fireplace.

It is about 24¼ x 27¼ inches, with a narrow flange all around, and bears the date "1764," and the words "Carlisle Furnace," and what is intended for the names Thornburgh and Sanderson, misspelled and clumsily executed. The design, on the other hand, of the twisted column, arch, and tulip pattern is well executed and bears such a marked general resemblance to *Fig. 16*, of the brochure alluded to, as to suggest identity. Inspection, however, soon shows variations in details; but the panel containing the name of the furnace, the figures of the date, and some other details seem, so far as comparison with a half-tone instead of the original will permit, to justify the inference of identity of portions of the mold, certainly of the caster. In regard to the "Delight of Warwick," as *Fig. 16* is named by Professor Mercer, he remarks that it is "half-German, half-English, the ill-spelled words *Iahn* (Johann) *Pot* (Potts) *and Warck Furnec* (John Potts and Warwick Furnace), and the German legend '*Las den Besen und thue Gutes*' (eschew evil and do good), betray the handiwork of a German designer working at the Warwick Furnace, near Pottstown, Pa., in 1764." He suggests that one or more German casters, finding employment from time to time at Warwick and Durham furnaces, carried their wooden molds with them. The point of peculiar interest in connection with the Carlisle casting is that it seems to carry the influence of the early Pennsylvania German artistic craftsmen to this then remote point west of the Susquehanna, and into a community not regarded as belonging to the German portion of the State, and to a furnace non-German in its origin and control, possibly the first fur-

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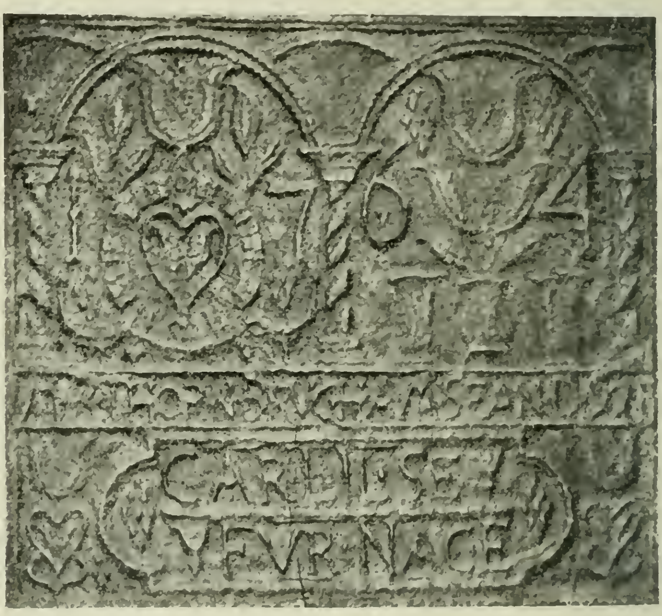
* Presented to the Hamilton Library Association of Carlisle, Pa., by Miss Emma Aberle.



Decorated stove-plate, Cumberland County, Pa., 1764. (Original, 24¼ x 27¼ inches.)

nace, or at least as early as any, west of the Susquehanna. There was a bloomery and forge at Spring Grove, York County, as early as 1756, and Mary Ann Furnace at that place was erected on land leased for that purpose in 1762 by Geo. Ross (one of the signers) and Mark Burd. This furnace is suggested by James M. Swank, Secretary of the American Iron and Steel Association, as the first furnace in Pennsylvania west of the Susquehanna, as noted in Gibson's "History of York County." The Carlisle Furnace, however, better known in the accounts of it as the Carlisle Iron Works, located at Boiling Springs, on the Yellow Breeches Creek, in Cumberland County, was erected by John Rigbey & Co., on land patented by Richard Peters in 1762 and conveyed to them on the day following, and of which they were already in possession, and on which they had commenced the erection of a furnace. In 1764 the property was conveyed to a firm of six members, five from Philadelphia, one of whom was Robert Thornberg, and another, Francis Sanderson, of Carlisle. It was these latter names that the caster endeavored very awkwardly to introduce, transposing the "*r*" and "*u*" in Thornburg, inserting an "*e*" before the "*a*" in Sanderson, and so crowding it as to render it liable to be mistaken for an "*f*." In "Carlisle" the "*s*" and "*l*" have also been transposed. The substitution of the names of members of the firm in the place of the usual religious legend, in German, is regarded by Professor Mercer as an evidence of artistic decline. But when we consider that a German legend would not have been appreciated, perhaps even not enjoyed, by the Scotch-Irish dominant in that region, the omission hardly justifies such conclusion any more than does the awkwardness in execution of the English names. The "curious sundial-like medallion," to use the term employed by Professor Mercer, repeated on many of these plates, in the upper left-hand corner of this one, suggests a legend or motto, but, if so, it has eluded all efforts thus far to decipher it in this example.

DRYING COAL.

The very successful application of coal-dust firing to the burning of cement in rotary kilns and the extensive use that this system is now finding in the American cement industry direct attention to the means for pulverizing the coal to the required degree of fineness In order to pulverize coal economically and satisfactorily, it should not contain more than 1 per cent. moisture. The pulverizing capacity of a mill is nearly twice greater with coal containing only 1 per cent. moisture than with coal containing 2 per cent. This subject was discussed by C. O. Bartlett in a paper read at the recent meeting of the American Mining Congress at Deadwood, S. D. The moisture must be expelled from the coal without causing the coal to lose any of its volatile combustible. Two lots of coal will rarely dry alike, some coals giving up their moisture easily and freely, and others with difficulty. It appears that coals in which the ash is composed largely of silica dry easily and thoroughly, while those of which the ash is high in lime or clay are difficult to dry. It is very important to handle the coal in such a way that warm air in large quantity be brought in contact with every particle of it, which is best accomplished by passing the curreut of air from the dried material through that which is wet. It is never safe to pass the fire-gases through the drying coal. The ignition temperature of coals is variable. as is also the temperature at which they will give off their volatile combustible. In general, coal can be safely delivered from the dryer at about 150° F. without loss of gas, at 225° F. there is likely to be a small loss of gas, and that temperature cannot be recommended as good practice. It is necessary to use a fan blast to produce a sufficient current of air to carry off the moisture. This will carry off 3 to 5 per cent. of coal dust, which should be saved by passing the current into a brick-dust settling chamber, the walls of which will retain sufficient heat to prevent the moisture from condensing.—*Engineering and Mining Journal.*

ARTIFICIAL GRAPHITE AND SILICON.

Mr. FitzGerald, in a recent address, makes the following references to the production of graphite and metallic silicon in the electric furnace:

Very early in the manufacture of carborundum Mr. Acheson observed that when he heated his furnaces to an excessively high temperature the carborundum was decomposed, the silicon going off as vapor which burnt outside the furnace, or condensed in the cooler parts, while the carbon remained behind as graphite. This gave him the clue to a general method of manufacturing graphite from amorphous carbon by the decomposition of carbides. This has been developed into a successful business for the manufacture of graphite electrodes, which find a large use in electro metallurgical and electro-chemical processes; also for the production of graphite for use as paint pigment, lubricants, etc.

As regards silicon, a process has been developed for its manufacture. Hitherto silicon, in spite of the fact that it is one of the most widely distributed elements, has only been obtained pure with great difficulty; but now it can be manufactured at a comparatively reasonable price, and will no doubt form a valuable commercial product for the manufacture of silicon alloys and other purposes.

CHEMICAL SECTION.

Stated Meeting, held Thursday, October 15, 1903.

Catechu.

By W. E. Ridenour.

Catechu is known in the American market chiefly as cutch, without any modifying terms.

The mat, bag, and box, cutches mentioned in Fluckiger's Pharmacographia, are not at present found in commerce.

Difficulty was experienced to secure samples characteristic of the American importations. It was quite easy to get samples, but their origin could not be ascertained.

In buying cutch, samples and prices are submitted. You take your choice. The next time you wish to purchase, it is very uncertain that you can get the same quality as before. This is one of the points that has discouraged its use.

Brokers in dye-stuffs who formerly handled large quantities now practically carry none in stock.

Cutch or catechu ("Census Bulletin," No. 210) is obtained from the wood and pods of the acacia catechu and from the betel nut, both being native in India. Cutch appears in commerce in dark-brown lumps, which forms a dark-brown solution with water. It contains catechu tannic acid as tannin and catechin and is extensively used in weighing black silks, as a mordant for certain basic coal-tar dyes, as a brown dye on cotton, and for calico printing.

The United States Pharmacopœia, 1890, only recognizes an extract prepared from the wood of Acacia Catechu, and gives the following tests:

If a portion of catechu be digested with ten times its weight of alcohol, and the liquid filtered, the undissolved matter after being dried at 100° C. should not exceed 15 per cent. of the original weight.

The tincture diluted with 100 parts of water acquires a green color on the addition of ferric chloride T. S.

Upon incineration, catechu should not leave more than 6 per cent. of ash.

M. de Meyer (*Journ. de Pharm.*, 1870) affirms that the best method of detecting adulteration of catechu is to treat the drug with ether. Catechu of good quality, after repeated treatment with ether, loses 50 per cent. of its weight.

Ether extracts from cutch, catechin.

Allen's "Commercial Organic Analysis," vol. iii, part 1, in addition to the above tests, gives color reactions of aqueous solution of catechu with various chemicals.

Sadtler's "Industrial Organic Chemistry" gives the following tests for valuing cutch:

Catechu Extract.—Catechu is frequently adulterated, not only with mineral matter like sand and clay, but with starch, dextrin, sugar, blood, etc. The mineral matters will, of course, remain in the ash. This in normal catechu should not exceed 5 per cent. The starch may be detected by extracting the sample with alcohol, boiling the insoluble residue with water, and testing the cooled liquid with iodine, which will show by the blue color any starch present. An addition of alcohol to the aqueous solution will show by the production of a turbidity any notable quantity of dextrin. Blood may be detected by treating the sample with alcohol, and drying and heating the residue in a tube, when the ammonia and offensive decomposition products will be given off, or the coagulation of the blood albumen when the aqueous solution is boiled.

The value of catechu for dyeing purposes can only be determined by a dye test. For this purpose strips of cotton-stuff are immersed for half an hour in a catechu solution (for each gram of the cotton 50 cubic centimeters of a catechu solution containing 5 grams to the liter of water are taken and diluted with water if necessary). The strips are pressed out, and then the color developed by oxidizing in a hot solution of 1 to 2 grams of potassium bichromate to the liter of water.

A. Jossart (*Jour. Pharm. d'Anvers*, 1881) examined a catechu which was adulterated with 65 per cent. of ferrous carbonate.

Several samples of cutch were collected from various sources and submitted to the most important of the above tests. In addition to the dyeing test on cotton given by Sadtler, the same test was made, using strips of silk, which gave more pronounced colors. Also the solvent action upon cutch of several liquids was determined with the following results:

	Samples Marked.	Ash.	Starch.	Blood.	Color with Ferric Chloride.	Tannin.	Dextrin.
	A. & D., before being Pr.	3·6	—	—	Brown Green No Ppt	40·0	Heavy
	A. & D., new lot	6·8	—	—	Brown Green Ppt.	49·6	—
	A. & D., Bell brand	3·5	—	—	Brown Green and Ppt.	67·6	—
No. 1.	Liverpool, Woodward . . .	3·9	—	—	Green and Ppt.	36·0	—
No. 2.	Liverpool, Woodward . . .	6·1	—	—	Brown and Ppt.	58·8	—
	Philadelphia	·4	—	—	Brown and Ppt.	72·8	—
	A. & D., high grade	4·2	—	—	Green Ppt.	62 8	—
	8418, Scharunpoor, India .	4·3	—	—	Green	41.6	—
	8417, Scharunpoor, India .	3·9	—	—	Green	44.0	Trace
	9919, No. West Prov., India	10·1	—	—	Green	35·6	—
F.	3615, Pondicherry, India . .	58 5	Heavy	—	—	·8	—
	8569, Scharunpoor, India .	1·2	—	—	Brown Green	34·8	Heavy
	McK. & R., Catechu	2·7	—	—	Brown Green	34·4	—
	McK. & R., Terra Japonica	4 6	—	—	Green	25·6	—
	S. D. & E. Co. —— A.	1·5	—	—	Brown Green	28·4	Heavy
	S. D. & E. Co. —— B.	11·7	—	—	Brown Green	22 8	Heavy
	P. C. P. Acacia Catechu . .	1·8	—	—	Brown Green	30·8	Heavy
	Immedial Cutch —— G.	60·1	—	—	—	—	—
	Immedial Cutch —— O.	60·3	—	—	—	—	—
J. R.	Straits Settlement, Port of Shipment, Singapore — Woodward, Liverpool . .	6·5	—	Slight Odor	Brown	2·4	—

	Samples Marked.	Hot Ethyl Alcohol.	Ether.	Acetone.	Paradehyde.	Fusel Oil.	Purified Methyl Alcohol.	Water.
	A. & D., before being Pr.	60·1	10·6	54·9	14·2	57·5	64·7	79·6
	A. & D., new lot	31·7	·4	2·5	1·6	6·0	55·9	82.0
	A. & D., Bell brand	83·5	·7	38·4	6·0	16·2	86·4	87·6
No. 1.	Liverpool, Woodward	39·0	1·3	5·1	2·5	13·2	47·6	72·8
No. 2.	Liverpool, Woodward	50·6	·3	17·2	·6	11·3	81·5	89·2
	Philadelphia	87·2	6·0	83·5	2·1	82·6	86·2	88·8
	A. & D., high grade	70·1	2·0	62·5	1·1	21·9	79·6	82·8
	8418, Scharunpoor, India	80·6	21·2	81·0	13·8	88·5	77·4	75·6
	8417, Scharunpoor, India	75.2	36·4	71·4	24·2	83·8	70·0	82·8
	9919, No. West Prov., India	62·4	23·6	59·6	32·0	64·4	69·2	70·4
F.	3615, Poudicherry, India	9·8	3·8	5·6	4·8	11·8	12·8	14·4
	8569, Scharunpoor, India	62·0	12·2	53·2	12·2	62·0	68·4	88·8
	McK. & R., Catechu	57·2	·6	7·0	2·0	16·8	60·2	74·0
	McK. & R., Terra Japonica	66·4	27·2	56·0	7·4	64·8	72·6	76·0
	S. D. & E. Co. —— A.	62·6	31·0	58·4	19·0	75·8	65·4	86·0
	S. D. & E. Co. —— B.	40·0	13·0	32·0	8·6	53·0	41·4	72·4
	P. C. P. Acacia Catechu	61·6	18·2	50·6	11·8	62·4	64·2	83·6
	Immedial Cutch —— G.	—	—	—	—	—	—	—
	Immedial Cutch —— O.	—	—	—	—	—	—	—
J. R.	Straits Settlement, Port of Shipment Singapore — Woodward, Liverpool	53·2	·8	14·4	·4	19·4	81·0	92·0

Solubility.—·500 grams of the finely powdered sample are digested over night in 15 cubic centimeters of the solvent. The liquid is filtered through paper into a tarred dish, and the residue treated with two successive portions of the solvent, 15 cubic centimeters each. The combined filtrates are evaporated to dryness and the residue dried to a constant weight at 100° C. in an air-bath.

The hot alcohol extraction gives the most uniform and concordant results; approximating the tannin contents. But it is no criterion of the dyeing value, as the highest alcoholic soluble samples give the lightest colors on cotton and silk. The estimation of tannin also gives no indication of its dyeing value, as the samples highest in tannin value dye the lightest colors.

The hide-powder method was used exclusively for the estimation of the tannin.

The methyl alcohol results agree very closely to those obtained with ethyl alcohol, hot extraction, and there is no reason why methyl alcohol cannot be substituted for the latter.

The other solvents are unsatisfactory in their action. The results do not agree with those obtained with either ethyl or methyl alcohols or the tannin contents.

Chloroform extracts nothing from catechu and for this reason is omitted from the tables.

The solvent action of acetone upon the various samples of cutch is very strange and some of the results are impossible to explain, *i. e.*, in samples A. and D., new lot, Liverpool No. 1, Liverpool No. 2, and McK. & R. catechu, the acetone soluble portion is very much smaller than the percentage of tannin.

Henry Trimble ("The Tannins," vol. ii) states that acetone has been found very valuable for the extraction of the oak tannins.

My own experience has shown that acetone extracts tannin from Aleppo and Chinese galls very thoroughly, and yet it seems to have a selective action upon the tannin in different samples of catechu.

The sample marked Philadelphia is the only one that answers all the requirements of the United States Pharmacopœia.

The percentage soluble in ether in all samples examined is much below the standard recommended by M. de Meyer. The value of this test is much to be doubted, as ether dissolves the catechin, then samples of catechu containing 50 per cent. or more of tannin cannot answer this test.

The ash is as a rule much lower than 6 per cent. Those of higher percentage indicate intentional adulteration.

Sample 3615 is a mixture of clay, starch and organic coloring matter. Samples Immedial Cutch G. & O. are mixtures of sodium and potassium, chloride, sulphide, and sulphate with an aniline dye. The manufacturer claims they are neither natural nor synthetic.

The ash of sample J. R. is very little in excess of U.S.P. requirement, but 2·3 per cent. is sodium carbonate.

Sample J. R. is a puzzle. The ash is not excessive.

The ethyl alcohol and methyl alcohol solubles are good and the dye test very good, but the percentage of tannin present in the sample is abnormally low; also there is one strange reaction which did not occur with any other sample; the water solution of the residue from the alcohol extraction, which was of a very deep red color, gave a heavy precipitate with Iodine T. S. and a colorless liquid.

Sample P.C.P. Acacia Catechu is from the museum of the Philadelphia College of Pharmacy and is at least twenty years old.

Samples 8418, 8417, 9919, 3615, 8569 are from the Philadelphia Commercial Museum.

Sample J. R. is from Mr. T. B. Woodward, Liverpool, Eng., from whose letter I quote: "It is a production from the Straits Settlement and the port of shipment is Singapore. The brand is J. R. It is the strongest in tannin of all the cutches, and indeed is the strongest in tannin of any extract yet produced. Though it does not suit many dyers who require cutches giving a yellower shade of brown, it is still very largely used for dyeing silk and cotton goods. My largest sale for it, however, is for tanning mackerel and herring fishing nets, sails, and fishing lines. The object is to preserve the fishing gear, which it does more efficiently than any other agent I know. Some of the telegraphic construction companies use it extensively for preserving the fiber used in the construction of their cables. The reddish color it gives does not please our tanners, who are extremely conservative and hard to move."

There are, therefore, two distinct methods of examining cutch, according to what uses are to be made of it. If for tanning or medicinal purposes, then the ash, ethyl or methyl alcohol soluble and tannin should be estimated; if for dyeing purposes, then only a practical dye test can decide.

To what principle in catechu is the dyeing value due?

Five grammes of cutch are dissolved in one liter of hot water, allowed to cool and filtered.

This solution is detannated by passing through hide-powder, the percolate giving no precipitate with tannic acid or a color with ferric chloride. A strip of silk, dyed in this solution, which was of a deep red color, and developed with potassium bichromate, gives very little color, quite a contrast with silk dyed with original catechu.

Five grammes of the purified tannin are then dissolved in one liter of water and a strip of silk dyed under the same conditions gives a deeper color than that developed by using the original catechu.

Preparation and Purification of Tannin from Catechu:—Extract the powdered cutch with acetone, and evaporate the clear liquid to dryness; dissolve the residue in hot water, allow to cool and add water until it ceases to give a precipitate. The clear filtrate is shaken with ether to remove catechin, and then the tannin is removed by agitation with successive portions of acetic ether. The acetic ether is recovered, the residue dissolved in water and diluted until it ceases to give a precipitate, and the clear filtrate agitated with acetic ether; this process of solution in water and shaking out with acetic ether is repeated until the tannin is completely soluble in water.

The tannin is then dissolved in a mixture of alcohol and ether, filtered, and then evaporated to dryness under reduced pressure, which gives the tannin in a porous condition.

Properties:—Catechu tannin, as prepared by the above process, is of a reddish-brown color, and completely soluble in water and alcohol.

Ether containing alcohol and water dissolves it, but stronger ether has little solvent action.

A 1 per cent. solution of this tannin in water gives the following reactions:

Ferric chloride, ...	Dirty green ppt.
Ferrous sulphate	No change.
Lead acetate	Whitish ppt.
Potassium bichromate.	Red-brown ppt.
Ferric acetate	Olive-green ppt.

The reactions are practically those of all tannins which give green precipitates with ferric salts; to the same class belong the tannins from mangrove, canaigre, hemlock, rhatany and the oaks.

MEASUREMENTS OF RADIO-ACTIVITY.

In newspaper references to the gift of radium recently made to the New York Museum of Natural History by Mr. E. D. Adams, the activity of the material was expressed in numbers, with no explanation of the manner in which the numbers were determined. In the paper read by Mr. Hammer in April before the American Institute of Electrical Engineers and the American Electro-chemical Society, which in part treated of radium, this explanation appears.

To measure radio-activity, Prof. and Mme. Curie measure the electric conductivity which a radio-active substance imparts to air, and take as unit the radio-activity of uranium. The radio-active substance is placed on one of two condenser plates, which are charged to a high potential. The air between the condenser plates is rendered a conductor of electricity by the presence of the radio-active substance, and in a certain time a certain quantity of electricity will pass from this condenser plate to the other plate. This quantity of electricity passing over in a certain time is determined and serves as a measurement of radio-activity. If the quantity of electricity passing from one plate to the other in a certain time is x times the quantity which would pass in the same time if uranium was substituted for the tested radio active substance, it is said that the latter has the radio-activity x. The problem is, therefore, to measure the quantity of electricity passing from the one condenser plate to the other in a certain time. This may be done in two essentially different ways. Either by an electrometer method the quantity of electricity may be measured which during a given time passes over to the previously uncharged condenser plate. Or the time may be measured in which this plate when connected to an original charged gold leaf electroscope discharges it. For these latter measurements the gold leaf electroscope may be observed by means of a telescope provided with a micrometer scale and the time taken for the discharge of the electroscope is taken by means of a chronometer. By such methods, the Curies say, according to Mr. Hammer, that they can detect the presence of a radio-active substance in so minute a quantity that it would require 5,000 times this amount to show at all in the spectroscope. And it is stated that this method of electrical analysis is thousands of times more sensitive than spectrum analysis and millions of times more sensitive than chemical analysis.—*Electrical World.*

LIQUID HYDROGEN.

Olszewski describes in the Cracow *Bulletin* a new apparatus for the liquefaction of hydrogen, differing from his previous models in having both regenerators and the intermediate cooler for receiving liquid air all placed in a common vacuum chamber. The apparatus is said to work faultlessly.

CHEMICAL SECTION.

Stated Meeting, held Thursday, March 19, 1903.

What Physical Chemistry has Done for Chemistry.

By Harry C. Jones.

[ABSTRACT.]

Physical chemistry has furnished us with several generalizations which have greatly modified our methods of dealing with chemical phenomena. Among these may be cited the Theory of Electrolytic Dissociation, the Law of Mass Action, Faraday's Law, the basis of chemical valence, and the Phase Rule.

Of these generalizations time will permit us to consider only one or two, and we can only make a few applications of the most important of them all—the Theory of Electrolytic Dissociation.

A word or two in reference to the origin of the theory.

Osmotic Pressure.—When a solution of any substance is brought in contact with the pure solvent, or with a solution of different concentration, at the surface of contact of the two solutions there exists a pressure which tends to drive the dissolved substance from the region of greater to the region of lesser concentration. This is known as osmotic pressure.

The first to measure the magnitude of this pressure was the botanist Wilhelm Pfeffer, who found that salts gave a greater osmotic pressure, for equivalent concentrations, than solutions of substances like cane sugar.

Origin of the Theory of Electrolytic Dissociation.—It remained for Van't Hoff to point out that the electrolytes in general—acids, bases, and salts—exerted a greater osmotic pressure than the non-electrolytes. He also showed that osmotic pressure is a property which depends only upon the *number of parts* of the dissolved substance in a given volume of the solvent, and not upon the nature of the parts. Since osmotic pressure depends only upon the ratio between the number of parts of the dissolved substance and the number of parts of the solvent, and since electrolytes exert an osmotic pressure that is greater than can be accounted for on the basis of the existence of these substances in the molecular condition, we are forced to the conclusion that the molecules of electrolytes are broken down in solution into parts. These part molecules are called *ions.*

I cannot take up here the evidence bearing upon the theory of electrolytic dissociation, since it would lead much too far. Suffice it to say that the experimental evidence, as far as it has been established in a trustworthy manner, is practically unanimously in favor of the theory, and the amount of such evidence already at hand is simply overwhelming. The theory of electrolytic dissociation is as well established as most of our laws in science, and is to-day almost universally accepted by the leading chemists and physical chemists throughout the world.

Neutralization of Acids and Bases.—Let us now see what the theory has done for chemistry. Here again we can take up only a few of the many applications of this most important generalization. Take a class of chemical reactions that are more or less familiar to every one—the neutralization of acids and bases. It has long been known that when an acid is brought in contact with a base, both are neutralized, and when the solution is evaporated a salt is obtained. Since a different salt was obtained with every acid and base employed, we had as many new phases of the problem of neutralization as we had acids and bases to react.

This whole subject has been beautifully unified and simplified by means of our theory. Take the neutralization of hydrochloric acid with sodium hydroxide. Hydrochloric acid in dilute solution is a mixture of hydrogen ions and chlorine ions:

$$\mathrm{HCl} = \overset{+}{\mathrm{H}}, \overset{-}{\mathrm{Cl}}.$$

Sodium hydroxide in dilute solution is a mixture of sodium ions and hydroxyl ions:

$$\mathrm{NaOH} = \overset{+}{\mathrm{Na}}, \overset{-}{\mathrm{OH}}.$$

When these solutions are brought together we have:

$$\overset{-}{\mathrm{Cl}}, \overset{+}{\mathrm{H}} + \overset{-}{\mathrm{OH}}, \mathrm{Na} = \overset{+}{\mathrm{Na}}, \overset{-}{\mathrm{Cl}} + \mathrm{H_2O}.$$

What takes place and all that takes place in the above case is the union of the hydrogen ion of the acid with the hydroxyl ion of the base, forming a molecule of water. The anion of the acid, chlorine, and the cation of the base, sodium, remain after the process of neutralization in exactly the same condition as before neutralization took place, and a salt is formed only when the solvent which dissociated the salt into its ions is removed. We may now discuss the subject of neutralization in general. We may represent any acid by—

$$\overset{-}{\mathrm{R}}, \overset{+}{\mathrm{H}}, \text{ where } \overset{-}{\mathrm{R}}$$

is the anion, which differs in composition for every acid, and the cation hydrogen which is common to every acid. Similarly, we may represent any base by—

$$\overset{+}{\mathrm{R}}, \overset{-}{\mathrm{OH}}, \text{ where } \overset{+}{\mathrm{R}}$$

is the cation of the base. Its composition varying with every base, and hydroxyl is the anion common to all bases. When any base reacts with any acid, we have:

$$\overset{-}{\mathrm{R}}, \overset{+}{\mathrm{H}} + \overset{-}{\mathrm{OH}}, \overset{+}{\mathrm{R}} = \overset{-}{\mathrm{R}}, \overset{+}{\mathrm{R}} + \mathrm{H_2O}.$$

Water is always formed, and the anion of the acid $\overset{-}{\mathrm{R}}$, and the cation of the base $\overset{+}{\mathrm{R}}$, remain in the solution after the process of neutralization in exactly the same condition as before neutralization took place. In order to obtain the salt the water which holds the ions apart must be removed.

Neutralization, then, in terms of our theory consists in the formation of a molecule of water from a molecule of the acid and a molecule of the base, and in nothing else. One process of neutralization is, therefore, exactly the same as any other process of neutralization, regardless of the nature of the acid or the nature of the base involved. If this is true it is very important, since it refers all the processes of neutralization to a common cause—the union of the hydrogen ion of the acid with the hydroxyl ion of the base.

Heat of Neutralization.—We have a means of testing this crucially by experiment. If the process of neutralization is independent of the nature of the acid and the nature of the base, the amount of heat set free when any completely dissociated acid acts on any completely dissociated base in equivalent quantities, will be a constant.

The fact is that a *constant amount of heat* (13,700 cals. is liberated when a gram-equivalent weight of any completely dissociated acid is brought in contact with a gram-equivalent weight of a completely dissociated base. A few examples will make this clear:

$HCl + NaOH = 13{,}700$ cals.
$HNO_3 + NaOH = 13{,}700$ cals.
$HClO_3 + NaOH = 13{,}600$ cals.
$KOH + HCl = 13{,}700$ cals.
$LiOH + HCl = 13{,}700$ cals.
$\frac{1}{2}\ Ca(OH)_2 + HCl = 13\ 900$ cals.

If we vary the nature of the acid or the nature of the base, the amount of heat set free is a constant to within the limit of experimental error. Fact and theory are thus in perfect accord.

Thermoneutrality of Salts.—Another application of the theory of electrolytic dissociation in thermochemistry is interesting and important. It has long been known that when dilute solutions of neutral salts are mixed there is no thermal change—heat is neither liberated nor absorbed. This is the well-known law of the thermoneutrality of salts. While the fact was established beyond question, and various suggestions had been made to account for it, it was generally conceded that no one of these was at all satisfactory. The explanation to-day is very simple. Take the two salts, potassium chloride and sodium nitrate; a dilute, aqueous solution of potassium chloride contains only potassium ions and chlorine ions; a dilute solution of sodium nitrate contains sodium ions and nitric ions.

$KCl = \overset{+}{K}, \overset{-}{Cl}$
$NaNO_3 = \overset{+}{Na}, \overset{-}{NO_3}$

When the two solutions are mixed we have in the mixture potassium and sodium cations and chlorine and nitric anions, and nothing else. In a word, we have exactly the same ions in the mixture as in the solutions before they were mixed. There being no chemical change, there should be no thermal change, and such is the fact. The law of the thermoneutrality of salts could have been predicted from the theory of electrolytic dissociation, had it not been discovered long before the theory was discovered.

Color of Solutions.—Another class of chemical phenomena which had long attracted attention, but the significance of which was not clearly understood, was the color of substances, especially when in solution. Take, as an example, the color of the permanganates. The salts of permanganic acid with the alkalies and alkaline earths all have apparently the same color, which is the color of permanganic acid itself. This was tested quantitatively by Ostwald, who photographed the absorption spectra of these and other permanganates where the cation was colorless, and showed that they all had exactly the same absorption bands. We can see at once the explanation of this fact. Permanganic acid dissociates thus:

$$\overset{+}{\mathrm{H}},\ \mathrm{Mn}\overset{-}{\mathrm{O}}_4.$$

The color of the solution is not due to the hydrogen ions, since there are hydrogen ions in solutions of all acids and solutions of most acids are colorless. The color of the solution of permanganic acid must be due to the presence of the permanganic ion:

$$\mathrm{Mn}\overset{-}{\mathrm{O}}_4.$$

The color of the solution of any permanganate in which the cation is colorless, is due to the ion:

$$\mathrm{Mn}\overset{-}{\mathrm{O}}_4.$$

This can be seen at once, when we remember that any permanganate can be represented by the formula:

$$\mathrm{RMnO}_4,$$

in which R is a metal which yields a colorless cation. This compound would dissociate thus:

$$RMnO_4 = \overset{+}{R}, Mn\overset{-}{O}_4,$$

$\overset{+}{R}$ being colorless, the color of the solution must depend upon the colored ion:

$$Mn\overset{-}{O}_4.$$

We thus see at once why all such salts of permanganic acid must have exactly the same color.

Ostwald studied in all about 300 colored compounds, and found the theory of electrolytic dissociation most helpful in explaining phenomena similar to the above.

Modes of Ion Formation.—We have spoken thus far of molecules breaking down into ions in the presence of a dissociating solvent—

$$HCl = \overset{+}{H}, \overset{-}{Cl}$$
$$KOH = \overset{+}{K}, \overline{OH}$$
$$KCl = \overset{+}{K}, \overset{-}{Cl}$$

It must, however, not be concluded that this is the only way in which ions can be formed from molecules.

We may have one metal precipitated from a solution of one of its salts by another metal. When a bar of zinc is immersed in a solution of a copper salt, the zinc passes into solution and the copper is thrown out of solution. What takes place here is a transference of the electrical charge from the copper to the zinc. The copper having lost its charge, passes out of solution, while the zinc, having become an ion, passes into solution. This is obviously a mode of ion formation.

There are still other modes of ion formation. Take a bar of gold and dip it into chlorine water. Neither the gold nor the chlorine is in the ionic state before they come in contact. When they come in contact the gold becomes cationic and passes into solution, while the chlorine remains in solution, but passes from the molecular into the anionic condition. We have both cations and anions formed under conditions which are usually described as the solution of gold in chlorine water.

Solutions of Metals in Acids.—There are few chemical processes with which we are more familiar than the solution of metals in acids. Most metals dissolve in the strong acids, and from such solutions salts of the metals can be obtained on evaporation. This fact, which has been so long known, has only recently been satisfactorily explained. An acid dissociates, always yielding hydrogen ions, and anions whose nature depends upon the acid in question. This may be represented in general as follows:

$$HR = \overset{+}{H}, \overset{-}{R}$$

When such an acid is brought in contact with a metal the hydrogen ions of the acid give up their charge to the metal, and escape as hydrogen gas. The metal, having taken the charge, passes into solution in the ionic state. This is a perfectly general process, independent of the nature of the acid and independent in general of the nature of the metal. In reality it is a mode of ion formation. An ion which holds its charge less firmly—hydrogen—giving it up to the metal which holds the charge more firmly, the hydrogen escaping in the gaseous condition, the metal passing into solution.

Hydrolytic Dissociation.—Thus far the subject of electrolytic dissociation, or the breaking down of molecules into ions, has been considered. There is another kind of dissociation, which takes place in solutions of certain chemical compounds. When an alkali salt of a weak acid like carbonic acid is brought into the presence of water it shows an alkaline reaction. The fact has long been known, but no satisfactory explanation of it has been furnished. We have to-day a perfectly rational explanation of these and similar facts. There is at first a chemical reaction between the salt and the water, which takes place in the sense of the following equation:

$$K_2CO_3 + H_2O = KOH + KHCO_3.$$

This is known as *hydrolytic dissociation.* As soon at the products of hydrolytic dissociation are formed they are electrolytically dissociated by the water. In the above case the following ions are formed:

$$\mathrm{KOH} = \overset{+}{\mathrm{K}}, \overset{-}{\mathrm{OH}}.$$

$$\mathrm{KHCO_3} = \overset{+}{\mathrm{K}}, \overset{-}{\mathrm{HCO_3}}.$$

The hydroxyl ions from the dissociated water give the alkaline reaction, which is characteristic of such solutions.

We can thus see why the salts of weak acids react alkaline, and in a similar manner can understand why the salts of weak bases react acid. They are hydrolytically dissociated by water yielding the free acid, which then dissociates yielding hydrogen ions, which give the characteristic reaction to the solution.

Faraday's Law the Basis of Valence.—The lecturer then took up a discussion of Faraday's law as the basis of chemical valence. He pointed out that if we refer valence to the law of Faraday we place it upon an exact physical basis. If we do not, the name valence is more or less indefinite, being used with a great variety of meanings.

Importance of Energy Changes for Chemistry.—The lecture concluded with a plea for the necessity of dealing with the energy changes which take place when substances react chemically. Hitherto we have regarded these energy changes as subordinate, and have referred to chemical reactions as being accompanied by thermal change. This is confusing cause and effect. It would probably be much nearer the truth to say that thermal changes are accompanied by material transformations.

It was then pointed out that by studying material transformations alone we can never have an *exact science of chemistry*. This can be realized only by studying together with the products of the reaction, the thermal changes, the electrical changes, the light changes; in a word, the reciprocal transformations of intrinsic and other forms of energy.

ELECTRICAL SECTION.

Stated Meeting, held May 28, 1903.

Static Discharges in Electric Circuits.

BY PERCY H. THOMAS.

(*Concluded from page 398.*)

Partial Reflection.—There are other important cases of reflection in addition to those already treated. Suppose the medium or wire, instead of terminating absolutely as assumed above, changes to another "stiffer" medium or smaller wire in which the wave can continue. By stiffer medium is meant one of comparatively larger inertia and smaller elasticity. It is evident that on account of its smaller elasticity or capacity the whole energy of the wave cannot pass into the smaller section without an increase of intensity, but any increase of intensity must cause a portion of the wave to be reflected backward toward the source; that is, the original wave will divide into two parts, a portion going forward into the new medium, a portion going backward, and there will be a rise of potential at the reflecting point less than the double potential which is produced by complete reflection. The more rigid, that is, the smaller the capacity of the second portion of the line, the larger the portion of the original wave which will be reflected. It must be noticed, however, that the portion of the wave passing into the more rigid medium has as its initial voltage the voltage produced at the reflecting point by the original wave which is higher than the latter. As a consesequence, if the wave in the second portion of the line be itself afterward reflected, a rise of potential may occur greater than double the original wave. Similarly a still greater rise of intensity will occur with the passage of the second wave into a third medium more rigid than the second.

On the other hand, if the medium branch into two parts, each similar to the original, the energy of the wave will be divided into two parts and the intensity of each reduced. At the same time there will usually be a portion of the wave reflected backward with change of sign toward the source as well as portions going forward into the two branch lines. In other words, partial reflection by changing to either a more or less rigid medium divides the energy of the wave, reducing the energy at any one point. If a wave divide into two parts to follow two similar lines of equal length, these partial waves may be reflected at the ends of the branch lines, and since the two lines are the same length, will return at the same time and unite their energy at the junction point and send a reinforced wave toward the generator.

Electric Waves.—So far the waves treated have been linear waves, such as are confined to tubes or wires, but have not been limited to any particular form of wave, as light, water or electricity. However, examples have been given more particularly with reference to electric waves. From this point on, electric waves only will be considered and electrical terms only will be used.

In the electric circuit "elasticity in the medium" is represented by capacity. The stiffer the medium the smaller the capacity.

Weight or inertia is represented by inductance, the greater the inductance the greater the inertia.

The quantity of static electricity corresponds to the intensity or displacement in the wave.

The velocity of motion of the wave along the line is inversely proportional to the $\sqrt{C\ L}$. In air lines this approximates roughly the velocity of light, viz., 186,000 miles per second.

On account of the great velocity of the electric wave the ordinary generator frequencies of 25 to 100 cycles per second are not sufficiently rapid to produce a perceptible difference in time between the action at the generator and the motor end of the line; there is, however, actually, a very small lag. That is, a commercial circuit acts for all practical power transmission as a rigid transmission system, *e.g.*, a pair of gears. When, however, as by lightning disturbances, short-circuiting of line wires, or grounding of the circuit, a very sudden change of potential is produced, complete waves are produced in the line on account of the enormous frequency of such disturbances, and there is a great phase lag between the source and the end of the line. Any of these causes of abrupt change of potential are likely to be oscillatory, that is, cause an oscillation of potential at the discharge point backwards and forwards for a few periods. The number of such oscillations would, however, in commercial circuits, probably rarely exceed one-half dozen. These few, however, will send corresponding waves into the line, which may be reflected and may build up resonance or nodes and loops as conditions already described may determine.

It is these abrupt changes of potential not directly produced by the generator which for commercial circuits are properly designated by the term "Static Discharges." Their distinguishing characteristics is their extreme frequency of alternation, which is so high as to cause several complete waves to be formed in transmission lines of moderate length.

All the laws and properties of linear waves which have been here considered apply, of course, to these static electrical waves. For, example, static waves have their form and intensity determined by the nature of their source, that is, by the sort of change of potential at the point of the line where the exciting discharge occurs; and once formed each wave passes down the line without reference to what may subsequently occur at the source. This wave will preserve its form and intensity except for losses in the medium, here represented by the wire, or for complete or partial reflection. As before, complete reflection occurs either at an open-ended wire corresponding to an obstacle which produces as a maximum double potential at reflecting points and returns the wave towards the source without changing its sign; or, by a short circuit or very large condenser which prevents any rise of potential at the reflecting point, but returns the wave towards the source with its sign reversed. Partial reflection occurs with every change in the quality of the medium. This quality is measured by the capacity and inductance. If at the reflecting point the capacity of the lines be increased or the inductance be diminished, the rigidity is decreased and the wave is partially reflected; and the portion entering the new part of the line has a less voltage than the original wave, if the capacity be decreased, or the inductance increased, the rigidity of the medium is increased, partial reflection will again occur and the portion of the wave entering the new line will have a higher potential than the original wave.

Stationary nodes and loops or resonance may occur in an electric line as in any other case of linear wave motion, the critical condition to cause their occurrence being a number of similar waves following one another at uniform intervals in case of either resonance or loops, and in addition exact adjustment of the length of the line to the frequency of the alternating source in the case of resonance.

Effect of Static Waves in Commercial Circuits.—The net results as regards the operation of commercial circuits may be indicated quite briefly. Whenever a line is connected to a live circuit, whenever a line is accidentally grounded, whenever a short circuit occurs between two lines, or a lightning arrester discharges, or in case of any similar disturbance, there occurs at the point a very abrupt change of potential either up or down. The exact abruptness of such a change depends upon the local conditions and constants of that portion of the circuit at which the discharge occurs. In actual cases it probably varies between $\frac{1}{10,000}$ part and $\frac{1}{10,000,000}$ part of a second for each alternation. It is evident that this discharge is enormously rapid in comparison with 25 to 100 cycles per second of the generator frequencies. The frequency of 1,000,000 periods per second would give a wave length to the static wave in a transmission line of approximately 1,000 feet. Usually the discharges resulting from switching, grounding, etc., are oscillatory, but not very persistent; that is, each oscillation of the discharge is considerably less intense than the previous one, and after perhaps half a dozen alternations they become too weak to be serious. This means that no very high rises of potential will occur from resonance at these high frequencies, though a rise of two or three times the original potential might perhaps sometimes occur if conditions were very favorable. Usually, also, there will be a considerable diminution in the intensity of traveling waves, due to the fact that in their passage along the line they will suffer loss of energy from resistance and other losses, so that neither will double the original potential be produced by reflection, nor will the full values of the original waves be added together in case of resonance. This loss of energy in transmission will be especially effective in preventing a rise due to resonance since any increase in intensity of the wave greatly increases the losses in transmission.

To sum up, in commercial circuits, as a result of static disturbances, momentary rises of potential may be expected, more often at the ends of lines or other reflecting points, usually not over 50 per cent. greater than the abrupt change of potential which caused the wave; but in some cases where the length of line involved and other conditions are favorable for resonance a rise to two or three times the original voltage of the source may perhaps be found. There is, however, an additional phenomena which, apparently, somewhat increases the severity of these disturbances. This results from the heavy momentary charging current taken by a transmission line or other large capacity, when charged or discharged abruptly; this charging current tends to build up momentarily the voltage from which the line is being charged. Its effect is somewhat the same as would be experienced if the field strength of the generator were momentarily increased. This phenomena may add perhaps another 50 per cent. to the intensity of the static disturbance. These conclusions are based partly upon theoretical considerations, as indicated in the earlier part of the paper, and, at least as to the extent to which abnormal potentials may be expected in commercial circuits, partly upon a considerable number of actual tests which have been made by the writer in conjunction with the engineers of a number of large installations for the purpose of determining the practical effect of such disturbances. These tests have extended over a considerable range of time and diversity of location and have included widely different voltages and different lengths of line running to over 100 miles. In all cases the results obtained have been in accordance with the conclusions above.

Lightning.—The disturbances produced by lightning have their maximum intensity determined by different conditions from the waves produced by internal disturbances in the transmission system itself. The former are evidently determined by the intensity and proximity of the lightning flash and the protective apparatus, while the latter are determined directly by the generator voltage. Ordinarily the actual line disturbances produced by lightning are not extremely severe, and with efficient arresters on high tension circuits may be considered as not exceeding those due to the other causes of static disturbance. In exceptional cases, however, where lines are directly struck by lightning discharges of greater or less magnitude, there is an extreme rise of potential locally on the transmission line which is beyond the power of any commercial arrester to prevent. Fortunately, however, this discharge seeks the earth by the shortest path and will usually choose one or more line poles in the immediate vicinity of the discharge. Such poles will sometimes be chipped or split and sometimes completely splintered. This discharge may or may not cause a short circuit on the line; frequently will not. Although the main discharge reaches ground in all probability close by the point struck, there will, of necessity, as already explained, be waves sent in both directions down the line wires which will have an extreme maximum intensity at the start and which may do serious damage at the stations; but which are of a magnitude that may properly be handled by protective apparatus. Thus, though the direct violence of the stroke cannot be guarded against or resisted, yet, except in the very rare case where such discharge is in the immediate neighborhood of the station, very often no harm will result, provided the station apparatus be protected by efficient arresters.

Sources of Static Waves.—The common sources of static disturbance with the effects produced are summarized below.

(1) Charging a dead line from a live transformer not already supplying other lines, momentarily drops the potential of the transformer lead to zero; the generator then supplies charging current at a comparatively slow rate to bring the line to normal potential. In this case usually no wave will be produced, as the frequency is comparatively low. There may, however, result a certain momentary rise of potential.

(2) When a dead transmission line is charged from a system having a large quantity of electricity already stored in other lines connected to the same high tension bus bars, the potential of the new line is very suddenly raised to the potential of the system, and this sends an abrupt wave of positive sign along the line.

(3) Grounding or short-circuiting a charged line causes a sudden fall of potential, which sends a wave of negative sign along the line in both directions. This wave evidently causes no *rise* of potential at any point and is harmless except for a phenomena to be discussed later, under the head of Local Concentration.

(4) Opening a loaded line causes no rapid change of potential, since the load current produces a large volume of heated air, gradually cutting down the potential of the line.

(5) Opening an unloaded line has much the same effect as charging a line, since in opening the switch there will usually be a rapid charge and discharge of the line for a few alternations. That is, the instant after the line is free from the switch for the first time, the next alternation (being of opposite sign) will frequently be able to jump the gap and recharge the line momentarily, thus causing a static spark; that is, positive waves will be sent down the line.

Fortunately these potential rises are momentary and do not produce as severe a strain upon solid insulating material as similar potentials of long-continued duration. This results probably from the heat and mechanical inertia of the insulating material. Therefore, solid insulating material which is sufficiently strong to withstand the strains of normal operation will often not be punctured, even though it may be subjected to double normal voltage by these static strains; on the other hand, air distances subjected to such strains, including "surface distances" so called, can readily break down instantly from static strains, and, indeed, especially surface distances, may be and are more sensitive to static than other strains. It is necessary, therefore, in planning a high tension system to provide a very wide margin for air spaces at all exposed points and long surface distances between live parts to insure safety from static disturbances. On the other hand, very little increase is required in the actual thickness of solid material over that required to stand normal strains. This conclusion must be taken in conjunction with the discussion below under the head of "Local Concentration of Potential."

Most engineers do not appreciate the importance of this caution. Once a plant is installed with air distances too small, these will be an occasional cause of shut-down and loss until remedied.

In planning insulation distances it must be remembered that the striking distance of high voltages from 20,000 to 100,000 volts increases much more rapidly than the voltage, and that consequently for the higher voltages much more than proportionate spaces must be allowed. This phenomenon is one of the reasons why insulators for very high voltages have to be excessively large in comparison with insulators for perhaps 10.000 to 15,000 volts. The disadvantage to the insulator manufacture is further increased by the fact that the weight and material of the insulator increase somewhere nearly according to the cube of the linear dimensions, while the insulation strength increases more slowly than the first power.

It is of course customary and desirable to prevent as far as possible an abnormal rise of temperature above the earth by means of suitable lightning arresters. However, it is evident that lightning arresters cannot be placed at all points of the system where a rise of potential may be produced by static disturbances. They should usually be placed, however, where important apparatus is to be protected. At other points ample insulation distances, as outlined in the paragraph above, must be provided.

Local Concentration of Potential.—More serious than the momentary rise of potential just discussed is the strain produced upon coils connected to the high-tension circuits by static waves. It is well known that very abrupt waves or discharges pass only with great difficulty and slowly through choke coils, and that a static discharge will jump through considerable insulation rather than follow around the turns of a powerful choke coil. The high tension coils of transformers form extremely powerful choke coils and are subjected to very severe strains between the turns or layers when static waves reach their terminals. There is another way of looking at this phenomenon:

When a static wave reaches a transformer coil, on account of the enormously increased inductance and capacity of this winding over the line, its speed is greatly reduced. This means that when the beginning of the wave has reached a point, perhaps one-third of the way to the end of the coil, that the crest of the wave has reached the end of the terminal of the coil. Therefore, a difference of potential exists between the terminal and a point one-third the way through equal to the full potential of the static wave. This wave may be even greater than full-line potential, and the high-tension coil referred to may be one of a number which normally divide the full-line potential between them. Consequently the momentary strains upon the outer parts of the coil may be a great many times the normal voltage impressed by the generator. If the insulation between turns of the coil be not extremely good a spark will pass between them. This spark tends directly only to pass the energy of the static wave, which is very small in actual amount and almost harmless. Unfortunately, however, there may exist at this time a voltage between the turns between which the spark passes, maintained by the generator, which, though much smaller than the static voltage, is still able when once the insulation is broken down by the latter, to start and maintain an arc. Although the static spark of itself was nearly harmless, the arc maintained by the generator, if once started, will very likely destroy the coil. In case, however, that the normal voltage between layers or turns is very small, or in case the static spark occurs at an instant of time when the voltage of the generator is nearly zero, or, perhaps, under other conditions, the generator electromotive force will not be able to start a local arc. Fortunately, this will usually be the case. However, although each static spark which may pass between turns is in itself not particularly harmful, yet if for any reason a large number of such sparks pass in the same spot, a final deterioration of the insulation will result and a short circuit ensue at a later time, which may finally occur apparently without any connection with any static disturbance. As a matter of fact, static disturbances are very difficult to trace out in their effects within transformers.

It is evident that the same strain between turns in a coil will be produced by a negative wave as by a positive—if it be as abrupt. That is, a sudden dropping to zero of the potential of the transformer terminal produces the same strain as suddenly charging it to the same amount.

This local concentration of potential is neither an uncommon nor an uncertain phenomenon. It may be reproduced at any time in a laboratory or factory, or at a powerhouse, by a simple experiment, and undoubtedly occurs in commercial operation of plants. It is necessary only to cause a static disturbance near the terminal of a coil and measure by a spark gap the momentary voltage between the lead and points a portion of the way through the coil. Static waves are of great importance to the operating man, however, only on very high voltages.

It is evident that the condition which causes the local concentration of strain to be extremely severe is the abruptness of the static wave. The more abrupt the wave, the less distance will it have penetrated a transformer coil before the terminal has attained the full potential of the wave. This sort of strain is analogous to the breaking of a plastic body by a very sudden blow.

Protection of Circuits and Apparatus.—Protection of two types is required: (1) Lightning arresters to protect against abnormal rise of potential above the earth and the low tension circuits; (2) protection against local concentration of potential.

Grounds.—There are a number of ways, theoretically, in which static waves can be destroyed, or rather diffused, and prevented from doing serious injury. (1) The introduction of a choke coil in the line will divide a static wave in two parts, one portion passing on, the other being reflected back; the proportions of these parts for any given wave being determined by the size of the choke coil. If a number of these choke coils were placed at a number of points in the line so that reflection would occur several times, the wave would be distributed in a number of parts, each of which would act alone and be unable to do damage. However, this method is impracticable because each different static wave length would require a different choke coil to divide the static wave properly, and because such choke coils would seriously interfere with the normal operation of the system.

(2) Short branch lines would be excellent, as each would subtract a portion of the energy of the original wave, which would soon be reduced to a harmless magnitude. This method is of doubtful effectiveness, however, since the length of line necessary to actually withdraw energy from the original wave must be greater than the wave length of the static discharge. This length will vary greatly and might be so great as to render the cost of such branch lines prohibitory. Such lines must evidently be taken from some point of the main line, other than a reflecting point, or, as already explained, they will themselves experience an abnormal rise of potential. It is probable that branch lines and changes in the size or number of line wires (which has much the same effect) do help in many instances to reduce the severity of waves, but it is the opinion of the author that it is hardly feasible to devise such an arrangement with reasonable expense which can be relied upon to dissipate waves in all cases.

Both of the above methods fail also in cases where static waves originate near apparatus and do not pass through any considerable length of line before having an opportunity to do damage.

(3) Lightning Arresters. The only method in practical use at the present time is the employment of lightning arresters which are merely opportunities for the line to discharge to ground when reaching a potential sufficiently high above normal.

They may be made quite satisfactory for accomplishing this purpose at the particular point of the system to which they are connected, provided two secondary effects are neglected. (1) The arcing over the arrester following a discharge, which has been frequently discussed, and (2) the local concentration of potential resulting from the extremely abrupt negative wave caused by the reduction to earth potential of the circuit at the arrester. Various ways are proposed and used for the interruption of the arc in the arrester, all of which hinder the original function of the arrester to some extent; that is, the free discharge of the line. In high tension work the most successful means is series resistance in the discharge path of the arrester. By preventing any considerable flow of current from the generator this series resistance may be made to render almost any lightning arrester non-arcing. Every available means, however, should be used to reduce the amount of series resistance to a minimum, as it may seriously impede the discharge of the line. The use of non-arcing metal and a large number of small gaps in place of one large gap, as is done in nearly all commercial arresters, makes a very considerable gain in this direction. Another means for still further reducing the series resistance will be briefly described under the head of the low equivalent arrester.

The local concentration of potential produced by the lightning arrester discharge is not different from a similar effect due to other causes except that it is perhaps more severe since closer to the apparatus. It needs no separate consideration.

Short Circuits.—The prevention of dangerous local concentration of potential may be accomplished by several methods. (1) By insulating windings, especially near the terminals, sufficiently heavy to withstand the strains produced by static waves in the particular circuits in which this apparatus is to be used. This method is very satisfactory in its simplicity, and is entirely feasible for moderately high voltages. It is the method usually employed for this purpose.

(2) Windings may be so arranged, for example, by winding one turn per layer, as to very greatly reduce the static potential between layers and also the normal voltage between layers, and thus very much reduce the probability of the formation of a local arc in case of a static spark. This arrangement of windings extends the range of voltage for which insulation can be used commercially sufficient to stand static strains, but is inadequate in the highest voltages for the protection of the insulation between the coils or section of coils which are thus wound.

A more complete method, a method of prevention rather than resistance, which is available for higher voltages than those already mentioned, is the use of the static interrupter, which is substantially a magnified choke coil. Its function is to so delay the static wave in its entry into the transformer coil that a considerable portion of the latter will become charged before the terminal will have reached full potential. Protection by a choke coil will first be discussed.

If a very heavily insulated powerful choke coil be placed in the lead of the transformer, when a static wave approaches electricity will begin to pass in small quantity and will pass in gradually increasing quantity at later instants of time, so that the coil will be, comparatively speaking, gradually brought to full potential; meanwhile the volume of the static wave is being reflected and choked back and perhaps being discharged to the ground if there be a lightning arrester near. It is evident that this choke coil, to be effective, must be so proportioned as to delay the incoming wave enough so that the portion of the winding which has become charged when full potential is reached at the terminal shall be sufficient to withstand the strain of the full voltage of the wave. It is evident that such adjustment does not depend directly on the freqency or abruptness of the static wave, since both the transformer and the choke coil are similarly affected by the frequency.

But a choke coil sufficiently powerful to accomplish this result satisfactorily is found to be impracticable on very high potential circuits on account of the size, cost and interference with the operation of the system. However, if the arrangement of the static interrupter be used, that is, if a condenser be connected between line and ground behind the choke coil nearer the apparatus to be protected, this choke coil will absorb a considerable portion of the current actually passed by the choke coil, and the time required to pass

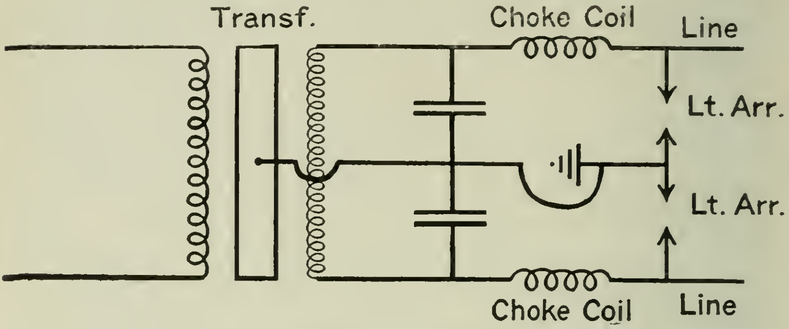


FIG. 3.—Static interrupter protecting transformer.

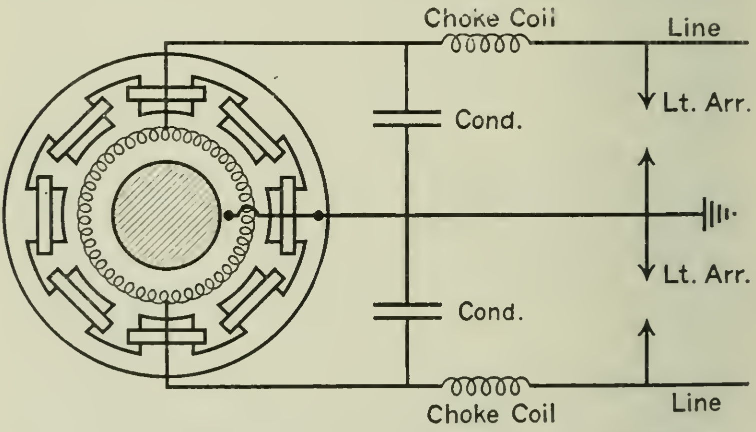


FIG. 4.—Static interrupter protecting high-tension generator.

sufficient electricity to charge the terminal will be much increased. With this arrangement a comparatively small choke coil may be used. The condenser has a very small electro-static capacity, and has no appreciable effect upon normal operation, and yet has a very powerful effect on the static wave on account of its extremely high frequency. As in the case of the choke coil, the static interrupter must be roughly proportioned to the transformer winding to be protected. The condenser must also be suitable for the voltage between line and ground.

If static interrupters be placed in each lead of high tension apparatus which may be injured by local concentration of potential, its windings will be amply protected against danger of short circuits from static wave either positive or negative. Such an arrangement is shown diagrammatically in connection with a transformer and a high tension generator in *Figs. 3* and *4*.

A large number of these interrupters have been manufactured and are in actual service.

Static Interrupters and Low Equivalent Lightning Arresters.—A short description of the salient features of some actual lightning arresters and static interrupters designed by the author for the purpose of protecting apparatus from static disturbances will be given.

The low equivalent A.C. lightning arrester consists of a number of $\frac{1}{32}$-inch air gaps between non-arcing metal cylinders in series with non-inductive resistance. A portion of the resistance, called shunt resistance, is shunted by a second set of air

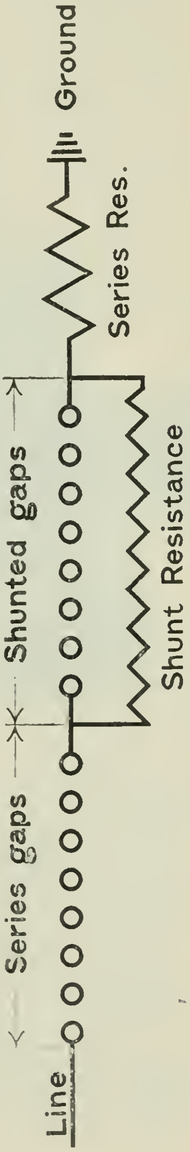


FIG. 5.—Diagram of low equivalent lightning arrester.

gaps called shunted gaps. The object of this arrangement is to reduce the amount of the series resistance through which the discharge must pass to ground. This arrester is diagrammatically illustrated in *Fig. 5*. The apparatus is shown in *Fig. 6*.

The series gaps withhold the line voltage and are chosen so as to break down at something between 50 per cent. and 100 per cent. rise of voltage above the earth. A portion of the series resistance is shunted by gaps so that the static discharge can pass around this portion, thus avoiding its resistance. It evidently is then necessary to suppress the arc from the generator which tends to follow through the shunted gaps. It is found that with a number of shunted gaps equal to the series gaps, the arc will be withdrawn from the shunted gaps by the shunt resistance when the shunt resistance does not exceed a proper value, which is a considerable portion of the total resistance in the arrester. A very marked gain in the reduction of the resistance offered to the discharge is therefore made by means of the use of shunted gaps and shunt resistance. It must be noted as well that no more voltage is required to cause a rise of potential to jump over all the gaps series and shunt than would be required to jump the series gaps alone, since on account of the shunt resistance the series and shunted gaps are broken down separately one after the other.

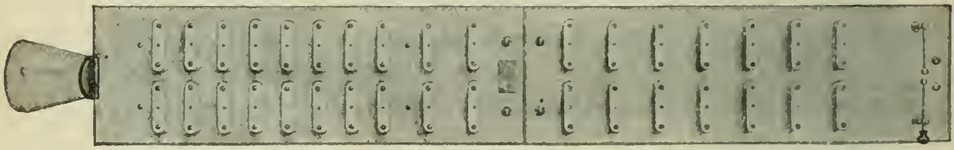


FIG. 6.—Low equivalent A. C. lightning arrester.

A static interrupter, see *Fig. 7*, consists of a choke coil in series with the line and a condenser connected between line and ground on the apparatus side of the choke coil. Since interrupters are used only on high voltage plants, coil and condenser are placed in oil tanks which are made self-cooling. The coils are extremely heavily insulated. The condensers are built up of specially prepared insulating paper and have rectangular copper plates with rounded edges and corners. There is a considerable amount of heat generated in condensers which is a difficult matter to dissipate on account of the poor heat-conducting quality of the insulating material. These condensers are all provided with ventilating ducts which allow a passage of oil from the bottom upwards at frequent intervals to the interior.

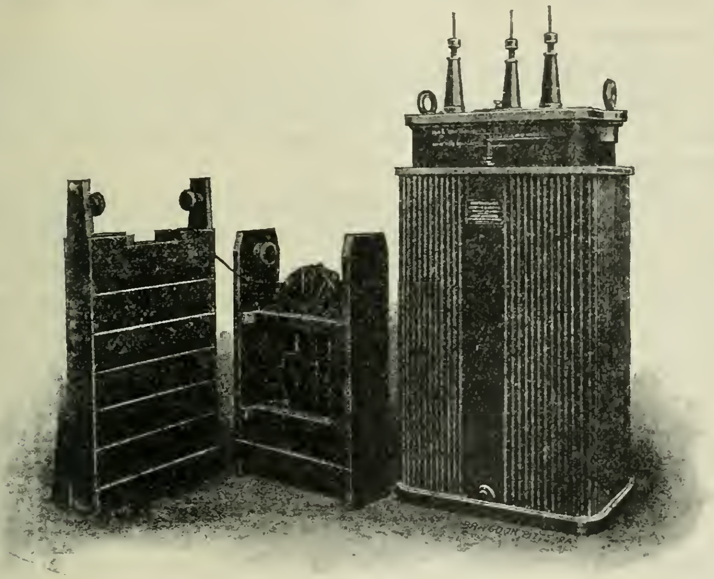


FIG. 7.—Static interrupter, showing coil and condenser out of case.

This condenser loss is quite an interesting phenomenon. Its amount increases as the square of the voltage upon the condenser, roughly, and is very rapidly increased with increase of temperature. The loss increases several times in amount between 50° C. and 100° C. This loss also depends upon the frequency of the circuit and for the kind of material used; for the dielectric in these condensers it increases approximately as the square root of the frequency.

Cables.—The high tension electric cable is in principle no different from the electric air line, but has a different insulating material, paper or rubber in place of air. This has the double effect of increasing its electrostatic capacity and changing the velocity at which waves progress. The increased electrostatic capacity tends to decrease the speed, but as the inductance of the cable is small this partially compensates for the increased capacity. The differences from the air line are differences in degree only and do not affect the passage of waves, reflection, resonance, etc., as already discussed. Consequently, no phenomena different from the air lines may be expected as a result of static disturbances.

Since the cable contains no coils of wire, no local concentration of potential will be found like that in transformer coils, and there is no occasion for the use of a static interrupter.

Conclusion.—There is in all probability nothing mysterious in static waves in electric circuits and nothing requiring for its explanation any new theories, and yet there is no subject connected with commercial power transmission which is so little understood by those who have not given it special attention, and in which it is so difficult to explain results. The difficulty arises not so much from intrinsic blindness in the subject as from the great difficulty of measuring and tracing these extremely rapid and invisible waves.

In a general way it must be expected that the surging about of the energy which is stored whenever a line is charged will cause increased potential at certain points. This should be provided for by placing suitable lightning arresters at all points where important and vulnerable apparatus is located. There will also be local concentration of potential in windings connected to the circuits as the result of all static disturbances. Such transformer or other coils should always be either sufficiently insulated or protected by choke coils or static interrupters or by some other suitable method.

The apparatus shown in connection with this lecture shows one arrangement designed by the author for protection of circuits and apparatus from static disturbances.

It is highly desirable that this subject should receive as much discussion as possible, and that further experiments should be tried and observations made by engineers and superintendents of power plants, and that all work together to determine the best methods of protection against this troublesome and elusive source of interruption of service and loss of apparatus.

PRODUCTION OF LEAD AND LEAD OXIDES.

It is important to note that while there has been a large increase in the consumption of lead in the United States during the last three years, the production of domestic mines remains at a standstill at about 280,000 tons. The additional quantity required by the home demand has not been, as might have been supposed, supplied by lead from Mexico and other foreign ores smelted and refined in this country. This lead, which is refined here in bond, has been almost entirely re-exported, the entries for consumption at home having been very small. The fact is that three years ago production had considerably outrun the demand then current, and the stocks carried by producers were very heavy. The increased demand has enabled producers to work off these stocks, and to reduce their holdings to normal amount, so that at the present time they are really low. The increase in consumption during the last three years has come partly from the great activity in building operations, which has required the use of large quantities of lead, partly from the increase in the demand for sheet lead for insulating cables and similar electric work, and partly from the demand for lead for use in various alloys.

The production of red lead, litharge and orange mineral has shown no very important increase during the last three years; nor has the production of white lead, although there was a considerable increase in the make in 1902. White lead has certainly suffered from the competition of other white pigments. If the improved Dutch processes that are now attracting so much attention, result in such a decrease in the cost of manufacture as is anticipated, white lead may be able to regain its lost ground.—*Eng. and Mining Journal.*

PRIZES OF THE SOCIÉTÉ INDUSTRIELLE DE MULHOUSE.

We have received a copy of the program of prizes to be awarded in 1904 by the Société Industrielle de Mulhouse. There are no fewer than fifty six competitions concerned with chemical technology, more than twenty dealing with the mechanical arts, and twelve with natural history and agriculture. Several prizes are offered with the object of improving and stimulating local industries. The program also contains full particulars of several large prizes of 5,000 francs, which are awarded for scientific work at intervals of in some cases ten, and in others five years.

The present publication takes the place of all previous issues, and copies of the program, in which certain changes have been made, can be obtained on application to the secretary of the society.

RADIO-ACTIVE ELEMENTS.

The opening address of Prof. W. N. Hardley, president of the Section of Chemistry, at the last meeting of the British Association for the Advancement of Science, contains the following interesting reference to the so-called radioactive elements:

"From the study of rays of measurable wave-lengths we have lately sailed under the guidance of M. Henri Becquerel into another region where it is doubtful whether all the rays conform to the undulatory theory. In fact some of the rays are believed to be charged particles of matter, charged, that is to say, with electricity. Beyond doubt they are possessed of very extraordinary properties, inasmuch as they are able to penetrate the clothing, celluloid, gutta percha, glass and various metals. They are, moreover, endowed with a no less remarkable physiological action, producing blisters and ulcerations in the flesh which are difficult to heal. It is an established fact that such effects have been caused by only a few centigrams of a radium compound contained in a glass tube enclosed in a thin metallic box carried in the pocket.

"From this we can quite understand that there is no exaggeration in the statement attributed to the discoverer, Professor Curie, by Mr. W. J. Hammer, of the American Institute of Electrical Engineers, that he would not care to trust himself in a room with a kilogram of pure radium, because it would doubtless destroy his eyesight, burn all the skin off his body, and probably kill him."

TECHNICAL NOTES.

Although the United States consumed last year approximately 520,537 long tons sulphur, exclusive of the sulphur recovered from the fumes from roasting blende, its own supply was little more than one-quarter of this quantity, chiefly in iron pyrites. The bulk of the demand is still satisfied by imports of brimstone from Sicily, and of iron and copper pyrites from Spain and other countries.——Metallic calcium is likely to become an important industrial product, if the methods of manufacture can be improved so as to reduce the cost. It is of value as a reducing agent and as a purifier of iron. The present cost of manufacture by electrolysis is about 45 cents per pound.——The steam turbine, which, many engineers think, promises to revolutionize the generation of power from coal, is, on account of its high speed, especially suited to the driving of electrical dynamos. The General Electric Company was quick to perceive this, in taking up the manufacture of the Curtis turbine engine, which it is now exploiting on a large scale.——Platinum is obtained in ordinary placer mining, in the Urals, California and elsewhere, but its occurrence in place in the rock is very rare and difficult of determination. It has been found in the peridotite, serpentine and olivine rocks of the Urals, but so finely disseminated that careful search has but rarely proved successful.——As greater depth is attained in Dolcoath mine, Cornwall, the finer becomes the tin; that is to say, the particles of cassiterite become more minute. This necessitates stamping to a greater degree, with additional care in treatment of slimes. With an ore containing only 1·5 to 1·75 per cent., the treatment is a difficult matter.—*Engineering and Mining Journal.*

PHYSICAL SECTION.

Stated Meeting, held April 23, 1902.

Electric Convection—A Historical Summary with a Bibliography.

By J. Frank Meyer.

If the theory of the electro-magnetic field as advanced by Maxwell in his celebrated treatise is true, the four following deductions from the theory should be true, and it should be possible to verify them experimentally:

(1) An electric charge in motion should produce a magnetic field.

(2) A varying magnetic field should produce an electric field.

(3) A magnetic pole in motion should produce an electric field.

(4) A varying electric field should produce a magnetic field.

These four points all seem to lack conclusive experimental verification, and so far only (1) and (2) have been attempted. However, a verification of any one of the four is practically proof of all the others.

It is said that as early as 1868 or 1869, the idea occurred to Professor Rowland that an electric charge in motion should produce a magnetic field. When Maxwell published his treatise in 1873 he suggests an experiment, but remarks that so far the experiment had not been tried.

If we have two parallel plane surfaces, electrified to surface densities σ and σ^1, then the mutual repulsion per square centimeter is $2 \pi \sigma \sigma^1$. If we now assume that a charge in motion is equivalent to a current, we may move the planes with a velocity v in their own planes, and this will cause an attraction between the planes.

If u and u^1 are the surface densities of current, it may be shown that the attraction is $2 \pi u u^1$ per unit area, u, and u^1 being measured in electro-magnetic units.

If the surface density in electrostatic measure is σv and $\sigma^1 v$, and n the number of electrostatic units in one electromagnetic unit, we have:

$$u = \frac{\sigma v}{n}; \quad u^1 = \frac{\sigma^1 v}{n}$$

Therefore:

$$2 \pi \sigma \sigma^1 = 2 \pi \sigma \sigma^1 \frac{v^2}{n^2}$$

and, finally,

$$v = n.$$

In other words, the ratio of the units is a velocity, and though it is not possible to move a charged plane with a velocity $v = 3 \times 10^{10}$ centimeters per second, it is possible to move the charge rapidly enough, so that if a magnetic effect does exist it can be measured.

Rowland* attacked the problem in this way: A hard-rubber disk, 21 centimeters in diameter, was gilded on both sides and mounted on a vertical axis. The disk thus rotated in a horizontal plane. Above and below the disk was a glass plate, also gilded. Above the upper of these two condenser plates was hung an astatic needle. The gilded disk was charged by bringing within $\frac{1}{3}$ millimeter of its edge a wire point connected to a battery of Leyden jars. When the disk was rotated about sixty-one times per second, and the electrification on the disk changed, a deflection of from 6 to 8 millimeters was observed on the scale.

To guard against conduction currents in the gilding on the disk, scratches were made through it. But the same deflections were obtained. The calculated and observed deflections agreed very well, but as the needle was always unsteady, the measurements obtained were not as accurate as might have been desired. The experiment has, however, been very generally accepted, and its results have been incorporated into the text-books, while the effect is known as the "Rowland effect."

In 1884 Lecher repeated the experiment with slight modifications, but with negative results. It has been suggested that his apparatus was not sensitive enough to detect the effect. This, however, hardly seems possible, for he used an astatic needle in the axis of a vertical disk, 200 cm. in diameter, charged to 5,000 volts and rotated with a speed of 200 revolutions per second. The charge was measured by an absolute electrometer.

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* *Pogg. Ann.*, clviii, p. 487.

Röntgen in 1885 used an apparatus similar to Rowland's in an attempt to observe displacement currents. He got deflections of his needle slightly larger than those obtained by Rowland, when the ungilded ebonite disk was charged by means of a brush discharge from points. Again in 1888 Röntgen used the same apparatus in order to investigate the action of a dielectric revolving in a homogeneous electrostatic field. The dielectric was rotated around a vertical axis between oppositely charged condenser plates. Precautions were taken to prevent the rotating disk from getting a real charge, and deflections of a few millimeters were obtained when the electrification on the condenser plates was reversed.

Professor Rowland and Mr. Hutchinson again took up the question in 1889.* They used two disks facing each other, and gilded on their inner faces. Each disk ran in a guard ring, between two condenser plates, on horizontal axes. The condenser plates were charged to about 5,000 volts, while the disks were kept earthed by brushes bearing on buttons sunk into the periphery of the disks. With speeds of about 120 to 125 revolutions per second, deflections of from 5 to 8 millimeters were observed. These deflections reversed in direction as the electrification was reversed. From this experiment a value of v was calculated, giving as a mean $v = 3{\cdot}19 \times 10^{10}$, the largest variations being between $3{\cdot}74 \times 10^{10}$ and $2{\cdot}26 \times 10^{10}$.

In the same year Professor Himstedt† used a very similar apparatus. He used two ground glass plates with a strip along the edge of each made conducting by rubbing graphite on the surface. His needle system was so placed that the upper and lower needles about coincided with the conducting strips. When the disks were charged, the condenser plates between which each disk ran being earthed, a deflection of the needle system was readily obtained. The deflection was in the direction to be expected, reversed in direction when the charge was reversed, and from 400 to 4,000 volts was proportional to the charge. Charges as high as 14,000 volts were used, but the proportionality did not hold beyond about 4,000 volts.

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* *Phil. Mag.*, **5**, xxvii, p. 445 (1889). Rowland's "Physical Papers," pp. 128, 138.

† *Wied. Ann.*, 38, p. 560 (1889).

About this time Lippmann* called attention to the reciprocal of the Rowland effect, and in 1897 Crémieu † took up this reverse problem: to find the mechanical force exerted on a charged body by a rapidly changing magnetic field. This force is a very small quantity. Crémieu attempted to detect it by rotating an aluminum disk between the poles of an electromagnet. The calculated effect was about 100 millimeters, but no effect could be observed. It should be noted, however, that in 1889 Professor Lodge did observe this effect, though not as satisfactorily as he desired.

The negative results in this experiment led Crémieu to investigate the Rowland effect, and after several years of work he concluded that an electric charge in motion does not produce a magnetic field.

Crémieu's method is new and ingenious, for instead of a magnetometer needle he uses a coil of wire and a galvanometer, thus noting the current induced in the coil by the changing magnetic field, if such a field does actually exist.

A solid aluminum disk 37 centimeters in diameter was mounted on a hard-rubber hub on a horizontal axis. Concentric with and around this disk was a coil of 13,000 turns of copper wire 0·15 millimeters in diameter. The coil was entirely enclosed in a hoop of brass and in series with it was a sensitive galvanometer. The diameter of the coil was 44 centimeters.

The disk was arranged to rotate between two thick iron plates 8 millimeters apart. A brass ring on the hub was put into connection with one terminal of a battery of Leyden jars, the other terminal being earthed. In this manner the disk was charged to about 5,000 volts.

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* *Comptes Rendus*, 89, p. 151 (1889).

† *Comptes Rendus*, 130, p. 1544 (1900).

Now on the assumption that a moving charge produces a magnetic field, a current should be induced in the coil, if the charged disk is rotated and discharged and again charged in succession. A commutating device was used in order to charge and discharge the disk, and at the same time commutate the current flowing through the galvanometer. No deflection whatever could be observed, though the theory predicted a deflection of about 20 millimeters.

Crémieu varied the experiment in several ways:

(1) The aluminum disk charged to 5,000 volts was rotated between iron plates. It was found, however, that sparks passed from the disk to the plates, the distance between the plates being only 8 millimeters. To prevent this, the iron plates were covered with lacquered glass plates 2 millimeters thick.

It was suggested by Pellat that even then the charge brushed across the space to the glass, leaving the disk uncharged. Crémieu tested this when the disk was at rest, and found that the charge did not pass over the gap. But it is possible that when the disk was rotating in the gap, only 1·75 millimeters wide with a speed of 110 revolutions per second, the charge did brush across. Only negative results were obtained from this experiment.

(2) A second experiment with the rotating disk covered with caoutchouc, the condenser plates being bare, also gave negative results.

(3) An ebonite disk gilded in sectors gave similar negative results.

(4) By rotating the disk in a brass drum with sides parallel to the disk, the sides being covered with mica on the inside and then gilded, no results were obtained. A needle was used to detect the effect in this form of the experiment. But when the brass ends were removed, leaving only the mica end, a slight deflection was obtained.

Mr. Wilson, of the Cavendish Laboratory, has pointed out that currents would be induced in the brass ends, with effects exactly opposite to those due to the disk, and that the experiment therefore confirms the theory.

M. Crémieu concludes that whenever the magnetic system is protected by a good conducting screen, it is not possible to obtain a deflection of the needle due to the magnetic field produced by the moving charge, and if any deflections do occur, they are due wholly to electrostatic effects. Therefore, as a final deduction, "open circuits" must exist, and Crémieu* proceeded to show their existences in the following manner:

An ebonite disk 37 centimeters in diameter and 2·5 millimeters thick, was gilded on one side in twenty-five sectors, a space of 1 centimeter being left ungilded between the sectors. This disk was mounted so as to rotate in a horizontal plane between two ebonite plates that served as condensers.

The plate facing the side of the disk not gilded was gilded over a sector twice as wide as one of the sectors on the disk. On the other condenser plate, exactly opposite the large sector, was placed a brush that made contact with the sectors on the rotating disk, as each one passed under the large sector on the condenser plate. This brush was connected to another 60° ahead of it, through a galvanometer.

Now if the fixed sector is charged from some source of electricity when a sector on the disk comes under it, the revolving sector acquires a charge by induction. This charge is then carried forward to the second brush where it is discharged. There is then a circuit partly convection and partly conduction. To find if the electricity in the convection part of the circuit produces a magnetic effect, a needle was hung between the brushes. The sector was charged to about 100 to 130 C.G.S. units, being distant from the rotating sectors 0·5 centimeter.

When the disk was rotated, a current of from 10^{-4} to 2×10^{-4} amperes flowed through the galvonometer, while there was no effect on the needle system. But a conduction current of same value deflected this needle 15 millimeters on a scale 4 meters distant.

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* *Comptes Rendus*, 132, p. 1108.

Crémieu concludes, therefore, that the electricity carried by the sectors has no magnetic effect, that is, that an open circuit exists.

In 1901 Pender* published the results of an investigation carried out under the direction of Professor Rowland, in which Rowland's previous results were confirmed in all particulars, thus contradicting the work of Crémieu.

Pender used two micanite disks, 0·356 centimeter thick, 30 centimeters in diameter, gilded on both sides and mounted on horizontal axes. Opposite each face of each disk was a condenser plate of hard rubber, covered with tin foil. These plates were about 1 centimeter apart, and were earthed. The disks were charged by means of brushes on brass rings from a Voss machine and six Leyden jars. Between the jars and disks was a reverser so arranged that the charge could be changed twelve to twenty-five times per second. The disks were rotated from 75 to 110 times per second.

Between the two inner condenser plates was a coil of 1,295 turns of No. 21 copper wire. This coil was 30 centimeters in diameter and enclosed in a metal case, which was connected to earth. The coil was connected through a commutator on the same shaft as the reverser to a sensitive galvanometer.

It was possible to rotate the disks in the same direction with similar charges, or in opposite directions with dissimilar charges. The latter method was used most frequently.

The direction of the galvanometer defection could be compared with that due to a current flowing in a test coil on the disk. This deflection was always in accord with Ampère's rule; the motion of a positive charge produces the same effect as that of a conduction current flowing in the direction of motion of the charge.

From 17 sets of observations, consisting of 18 determinations each, the mean value of v was found to be:

$$v = 3{\cdot}05 \times 10^{10}.$$

**Physical Review*, 13, p. 203, 1901.

The greatest variations obtained were:

$$v = 2{\cdot}75 \times 10^{10}$$
$$v = 3{\cdot}24 \times 10^{10}.$$

These results were further confirmed by rotating the disks, when similarly charged, in opposite directions when no deflections of the galvanometer occurred. Afterwards, scratches were made through the gilding on the disks, and the mean of readings gave for v the value $v = 1{\cdot}96 \times 10^{10}$.

Pender has repeated the experiment,* making greater variations in the speed of the disks and the charges were more varied, with confirmatory results.

Two other experiments have confirmed the effect. Adams† rotated copper spheres fastened to the ends of spokes of two wheels. The wheels were rotated with opposite charges of about 18,000 volts, and the effect was readily detected and measured.

Eichenwald‡ confirmed the effect by rotating a micanite disk between zinc condenser plates, using a needle system protected in a box of electrolytic copper.

The edge of the disk was covered with tin foil and the needle was placed over the edge. The calculated capacity of the condenser was 5×10^{-11} farads, and the convection current was $4{\cdot}5 \times 10^{-6}$ amperes. When a conduction current of $4{\cdot}5 \times 10^{-6}$ amperes was sent through the coil, the same deflection of the needle was obtained.

Dr. Pender has recently taken his apparatus to Paris, and it is hoped the reason for the contradiction between his work and that of Crémieu will be explained.

Supplementary Note.—Messrs. Crémieu and Pender have recently published the results of their joint work § carried out at the Physical Laboratory of the Sorbonne and arrive at the following conclusions:

(1) A charged continuous metallic disk turning in its own plane opposite fixed condensing-plates carries its charge with itself.

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* Pender: *Physical Review*, 15, p. 291.

† Adams: *Phil. Mag.*, **6**, 2, p. 285, 1901.

‡ Eichenwald: *Phys. Zeit.*, 2, p. 705.

§ Crémieu and Pender: *Phil. Mag.*, **6**, 6, p. 442, 1903.

(2) The *entrainement* of this charge produces a magnetic field in the direction demanded by the assumption of a magnetic effect due to electric convection, and in accord with the calculated value to 10 per cent.

(3) Charged sectors moving in their own plane, without the presence of any condensing-plates, produce a magnetic effect in the direction and of the proper size demanded by this same assumption.

The authors of this joint paper say further: "It is not for us to say whether these effects are really due to electric convection in the sense in which Faraday and Maxwell understood this expression, nor to decide whether they are in accord with the fundamental hypotheses of the accepted theories."

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BERLIN-ZOSSEN HIGH-SPEED ELECTRIC RAILWAY.

Continuing the experiments on the Berlin-Zossen military road, the German electrical engineers engaged on the work have now succeeded in pushing the speed of the car above 125 miles an hour. A cable dispatch from Berlin of October 6th, says:

"An electric car on the Marienfelde-Zossen experimental line reached a speed of 125⅘ miles an hour to-day, or a kilometer more than the highest previous record. The machinery and roadbed were unimpaired. The engineers are determined to try for still higher speeds and venture the opinion that they will be able to attain the rate of 140 miles per hour. The current was between 13,000 and 14,000 volts, capable of driving the car at the rate of over 200 miles. This power is reduced by transformers to about 450 volts. The car used to-day had four motors, having together about 1,100 horse-power. It was the car used in the previous tests this year, and is constructed on the Siemens-Halske system. Another car of somewhat different equipment as to motors and transformers has been built for additional high-speed tests.

"The lives of all on board the experimental car were heavily insured. A large party of engineers, military men and civilians gathered at Dallwitz, where the highest points of speed are reached in these experiments. A French observer remarked that the new sensation of the power of velocity inspired by the car's flight was worth traveling from Paris to see. There were twelve to fourteen persons on board the car, all technical men. They affirm that the motion of the car was no greater than that of an ordinary express train. A curious phenomenon accompanying the car is the continuous sparking of electricity from the six trolley arms.

"While the engineers do not believe a speed of 125 miles is practicable at present on the State railroads they are prepared to recommend a speed of 93 miles an hour between Berlin and Hamburg."

Correspondence.

SOME IMPORTANT POLAR NAVIGATIONS TO HIGH LATITUDES.
(Faustini-Balch.)

To the Secretary of the Franklin Institute:

SIR:—Among other interesting articles, the June numnumber of the *Journal of the Franklin Institute* contained one which was of special interest to me as a Dutchman (or let me rather say as one of Netherlandish origin, as I am a native of these colonies); it interested me especially as it contained much information about the bold expeditions of our forefathers; it was Dr. Arnoldo Faustini's Polar Navigations, translated by Edwin Swift Balch. But in one place I was sorry to note that it was sadly in error, that is to say, in the citation of page 421 of a sentence of Willem van Muyden's petition to the States General, and in the accompanying translation. Allow me to correct both. A somewhat literal translation should sound as follows:

"With a quantity of ships where never Christian man about had been, yes that they had passed 83 degrees where their ships had found a vast sea, without ice, flat pasture land with herbivorous fauna."

(Especially the last or final passus is quite different from the author's translation.)

The citation itself should read as follows:

"Met eene quantiteit schepen alwaar nooit christen mensch omtrent (instead of 'outrent') hadt geweest (instead of 'gewest') ja dat zy hadden gepasseerd 83 graden, alwaar haare schepen gevonden (instead of 'geronden') hadden eene ruyme (instead of 'ruyne') zee, zonder ys, vlak weidland met graseetende gedierte."

I hope this correction will prove to you the interest I feel for the Institute bearing the name of one as great as a patriot, as a politician and as a scientist, one of the most sympathetic of a broad host of sympathetic founders of a great republic.

I beg to add that John Lothrop Motley's "Rise of the

Dutch Republic" and his "History of the United Netherlands" contains many particulars about these early Arctic expeditions. In language as vigorous as it is fascinating, he describes the efforts of Barends, Heemskerk, and others to force their way through the polar ice.

I hope that you will be aware by this that we, descendants of the old "geuzen" ("Ce ne sont que des gueux," Berlaymont), do not lack in gratitude to so noble a representative of Franklin's great republic (I hope it will never become a "greater republic") as Motley, equally great as a politician, as a historian, jurist, poet, writer and patriot. Peace be with him!

Wishing you prosperity, material as well as moral and intellectual, with your admirable republic, I remain,

Respectfully yours,

H. VAN MEERTEN.

BUITENZORG, JAVA, July 11, 1903.

To the Secretary:

Heer van Meerten's letter is so flattering to Americans that it seems interesting to present it to the readers of the *Journal* as an expression of Dutch colonial opinion. Of the phrase to which he calls attention, I should like to say that I have not seen the Dutch original, but that I copied it literally from Dr. Faustini's paper, in which it reads as follows: "Si sono visitate, esse scrivevano, con una quantità di vascelli, le regioni estreme del Nord, ove mai nessun cristiano prima di noi vi fu, in paraggi molto al di là dell' 83° di latitudine nord, ivi trovandovi un *mare aperto*, senza ghiaccio e terre da pastorizia. '(Met eene quantiteit schepen alwaar nooit christen mensch outrent hadt gewest; ja dat zy hadden gepasseerd 83 graden alwaar haare schepen geronden hadden eene ruyne zee, zonder ys, vlak weidland met graseetende gedierte.)'"

E. S. BALCH.

PHILADELPHIA, November 1, 1903.

Notes and Comments.

THE ELIZABETH THOMPSON FUND.

The fund established by Mrs. Elizabeth Thompson, of Stamford, Conn., "for the advancement and prosecution of scientific research in its broadest sense," now amounts to $26,000. As accumulated income will be available in January next, the trustees desire to receive applications for appropriations in aid of scientific work. Preference will be given to those investigations which cannot otherwise be provided for, which have for their object the advancement of human knowledge or the benefit of mankind in general, rather than to researches directed to the solution of questions of merely local importance. Further particulars can be obtained from the secretary of the Board of Trustees, Dr. C. S. Minot, Harvard Medical School, Boston, Mass., U. S. A. It is intended to make new grants in January, 1904. Decided preference will be given to applications for small amounts, and grants exceeding $300 will be made only in very exceptional circumstances. The following lists of grants for 1902 has not previously been recorded: $125 to Dr. F. T. Lewis, Cambridge, Mass., for investigation of the development of the vena cava inferior; $150 to Prof. Henry E. Crampton, New York, for experiments on variation and selection in Lepidoptera; $100 to Prof. Frank W. Bancroft, Berkeley, Cal., for experiments on the inheritance of acquired characters; $250 to Prof. John Weinzirl, Albuquerque, N. M., for investigation of the relations of climate to the cure of tuberculosis; $300 to Prof. H. S. Grindley, Urbana, Ill., for the investigation of the proteids of flesh; $300 to Dr. Herbert H. Field, Zürich, Switzerland, to aid the work of the Concilium Bibliographicum (an additional grant of $300 was made June, 1903); $250 to Dr. T. A. Jaggar, Cambridge, Mass., for experiments in dynamical geology; $50 to Prof. E. O. Jordan, Chicago, Ill., for the study of the bionomics of Anopheles; $300 to Dr. E. Anding, Munich, Bavaria, to assist the publication of his work, "Ueber die Bewegung der Sonne durch den Weltraum;" $300 to Prof. W. P. Bradley, Middletown, Conn., for investigations on matter in the critical state; $300 to Prof. Hugo Kronecker, Bern, Switzerland, for assistance in preparing his physiological researches for publication; $300 to Prof. W. Valentiner, Heidelberg, Germany, for observations on variable stars.

LORD KELVIN ON RADIUM.

A special dispatch from London of September 12th to a New York daily newspaper says: "What Prof. C. V. Boys termed 'the miracle of radium' has naturally received much attention in scientific circles. At the meeting of the science branch of the British Association Lord Kelvin, in a paper which he read, made an interesting suggestion in connection with its perpetual emission of heat at, according to M. Curie's calculation, a rate of about 90 C. calories per gram per hour. He said that if the emission of heat at this rate went on for 10,000 hours, there would be as much heat as would raise the temperature of 900,000 grams of water 1° C. It seemed utterly impossible to

Lord Kelvin that this would come from the store of energy lost out of a gram of radium in 10,000 hours. It seemed, therefore, absolutely certain that the energy must somehow be supplied from without. He suggested that ethereal waves might in some way supply energy to radium, while it was emitting heat to matter around it. Lord Kelvin illustrated his theory by the following comparison: Suppose a piece of white and a piece of black cloth, hermetically sealed in similar glass cases, were submerged in similar glass vessels of water and exposed to the sun. The water in the vessel containing the black cloth would be kept very sensibly warmer than that containing the white cloth. Here the thermal energy was communicated to the black cloth by waves of sunlight, and was given out as thermometric heat to the water in the glass around it. Thus through the water there was actually an energy traveling inward in virtue of the waves of light and outward through the same space in virtue of thermal conduction. Lord Kelvin suggested that experiments be made comparing the heat emission from radium wholly surrounded with thick lead with that found in the surroundings heretofore used."

AN ARTIFICIAL NIAGARA AT ST. LOUIS.

An immense artificial cascade has been determined upon by the authorities of the St. Louis Universal Exposition as the center piece of the semi-circular lay-out of the principal buildings. The cascade itself will be divided into three parts—a large middle cascade, with a smaller one at each side, the water flowing directly into the head of the Grand Basin. In all, about 90,000 gallons of water per minute will be supplied at a head of 159 feet, forming the greatest artificial water effect ever attempted.

The water will be taken from the Grand Basin itself, and will be raised to the top of the cascade by a pumping station located under Festival Hall. The pumping machinery will consist of three 36-inch single-stage turbine centrifugal pumps, purchased from Henry R. Worthington, of New York City, each driven by a 2,000 horse-power Westinghouse alternating current motor. The total horse-power utilized will thus be 6,000, making this the largest electric pumping station in the world. The pumps and other pieces of machinery for this plant are now being installed at St. Louis.—*Iron Age.*

DOUBLE CARBIDE OF CHROMIUM AND TUNGSTEN.

Moissan and Kouznetzsw. The authors have obtained this new double carbide by heating in the electric furnace, in the carbon crucible, a mixture of 100 grams sesquioxide of chromium, 45 grams of tungstic acid and 30 grams of petroleum coke or sugar carbon. The current must not be of too great intensity, 400 amperes at 75 volts for five minutes being sufficient. Another method of obtaining the double-carbide consists in fusing in the electric furnace a mixture of metallic chromium, tungsten and a small quantity of sugar carbon in the presence of a large excess of copper, always avoiding as much as possible the carbon vapor of the arc. This mass is melted rapidly in a carbon crucible and the copper is maintained in ebullition for one or two minutes. After pulverizing and treating the regulus thus obtained with various solvents, smaller crystalline clusters of the double-carbide are obtained.—*L'Eclairage Elec.*, August 22d.

Book Notices.

Whittaker's Electrical Engineers' Pocket-Book. Edited by Kenelm Edgcumbe, A. M. Inst. C. E., etc. With 149 illustrations. (12mo, pp. vi + 456.) London and New York: Whittaker & Co. 1903. (Price, 3s. 6d.)

This pocket-book appears well arranged for the use of professional and practical electricians. A concise synopsis is given of subjects treated, bringing each up to date. The work contains the usual collection of useful formulas, rules, tables, and statistical data that are indispensable for reference. Special features that have been incorporated are sections on "Estimating for Electrical Machinery" and "Legal Information." These are written from the English viewpoint, but will doubtless prove useful to some American readers.

W.

The Mineral Industry: its statistics, technology and trade in the United States and other countries to the end of 1902. Edited by Joseph Struthers, Ph.D. Volume xi, supplementing volumes i–x. (4to, pp. xxx + 891.) New York and London: *The Engineeriug and Mining Journal.* 1903. (Price, $5.)

The eleventh volume of this important encyclopedia of the mineral and metal industries which has just appeared, is issued in the same form as the preceding ten volumes, to which it may be regarded as a supplement. The general method of treatment followed in the preceding volumes is retained. Under some fifty general heads, the statistics, technology and trade conditions of all the commercially useful mineral products and metals are dealt with by experts of acknowledged standing in their respective branches, the whole constituting an admirable résumé of the progress and present condition of these important industries.

"The Mineral Industry" has become an indispensable reference work to all who have to do professionally or commercially with the industries to which it relates. W.

Notes on Electric Railway Economics and Preliminary Engineering. By W. C. Gotshall. vi + 252 pages. Illustrated. New York, 1903. Published by the McGraw Publishing Company. (Price, $2.)

This book is based upon a series of lectures delivered at Lehigh University last spring, the subject of which dealt with the economics of the preliminary determinations and of the construction and operation of high-speed interurban electric railroads.

The book treats exclusively of high-speed interurban railways. Taking up the project from the preliminary office investigation of the probable earnings and expenses it carries it through the course of track location and construction until it is ready for operation.

Part of the book is devoted to a statement of the principles which should be followed in locating a proposed route so as to derive the maximum benefit from the territory to be served.

One of the most valuable parts of the book is Chapter VI, relating to the detail of the computation and determination of the probable passenger and freight gross earnings.

The detail costs of operation and their computation for different schedules are clearly discussed in Chapter VII. The author has placed at hand a method of accurately determining the costs of operation for almost any proposed system, and points out the danger of using the percentage of gross receipts methods now so commonly employed.

In Chapter X there is an excellent discussion of third rail vs. trolley systems, showing the applications and limitations of each.

The data relating to the determination of the probable cost of construction and of the mooted question of train resistance are very complete. Tables and diagrams are also given showing the relation between the energy consumed for different schedules and different distances between stops. The relatively great cost of high speeds is strikingly shown.

The best manner of keeping, systematizing and showing relative construction and operating data and records is also discussed.

The eighteenth chapter sets forth the controlling considerations governing the kind and character and consequent permissible cost of a proposed installation. The principles laid down are illustrated by an assumed case representing actual conditions.

The book concludes with a set of complete specifications for the construction of a moderate sized high-speed interurban electric railway operating over its own right of way.

With a few exceptions all of the full-size original drawings and diagrams which were used in the lectures have been reduced and reproduced for this volume, and appear at their proper places in the text.

Mr. Gotshall's book should be bound to be valuable alike to the practicing engineer and expert, and to the railroad manager, financier and investor.

W.

Cyanid-Prozesse zur Goldgewinnung. Von Manuel von Uslar unter Mitwirkung von Dr. Georg Erlwein. Mit 30 Figuren und 13 Tabellen im Text und 3 Tafeln. 8vo, pp. vi + 93. Halle a. S.: Wilhelm Knapp. 1903. (Preis, M. 4.)

This work constitutes volume vii of the series of Monographs on Applied Electrochemistry which is being issued from the press of this publisher. The volumes which have thus far appeared have been of a high order of excellence, and the present one is in no respect inferior to its predecessors. It treats of the subject generally in a brief introduction, then proceeds to a description of the McArthur-Forrest & Siemens-Halske processes, giving examples of the application of the method taken from various works. Then follows a chapter on the chemistry of the processes; and in conclusion a brief description of the various modifications of the cyanide process. Among the illustrations are plans and elevations of working plants. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, November 18, 1903.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 18, 1903.

Vice-President JAMES M. DODGE in the chair.

Present, 37 members and visitors.

Additions to membership since last meeting, 11.

The Secretary presented and read a letter from his honor, the Mayor of Philadelphia, transmitting a communication from the London Society for the Encouragement of the Arts, Manufactures and Commerce, offering a prize for a "Dust-Arresting Respirator," and inviting the participation of the members of the Institute in the competition. The prize in question, to be awarded under the terms of the Benjamin Shaw trust, will consist of a gold medal, or £20, "for the best Dust-Arresting Respirator for use in dusty processes and in dangerous trades."

A communication was also read from Dr. A. E. Kennelly, General Secretary of the International Electrical Congress of St. Louis, Mo., 1904, extending an invitation to the members of the Franklin Institute to co-operate in the work of the Congress.

The Secretary was directed to make suitable acknowledgment of these courtesies.

A special election was held to fill two vacancies in the Board of Managers. Dr. Persifor Frazer was elected to fill the place made vacant by the resignation of Mr. F. L. Garrison, and Mr. Chas. H. Howson was chosen to fill the vacancy caused by the elevation of Mr. James M. Dodge to the office of Vice-President.

Col. W. F. Morse, of New York, presented a paper on "The Utilization and Disposal of Municipal Waste," which was illustrated with the aid of numerous lantern photographs. The speaker described the various methods and apparatus employed, and gave some account of the results attained and of the situation of the work in the United States.

Dr. Charles F. Himes, of Carlisle, Pa., followed with an illustrated description of an interesting Decorated Stove-plate Casting, which is no doubt a relic of the earliest iron furnace established west of the Susquehanna River. The speaker's remarks embraced some references to the general subject of this interesting pioneer industry.

The chairman expressed the thanks of the meeting to the speakers of the evening, and announced the meeting adjourned.

WM. H. WAHL,
Secretary.

Committee on Science and the Arts.

[*Abstract of proceedings of the stated meeting held Wednesday, Nov. 4, 1903.*]

MR. CHAS. E. RONALDSON in the chair.

The following reports were adopted:

(No. 2300.) *Process for Utilizing Waste Metals.*—G. H. Clamer, Philadelphia.

ABSTRACT.—This process is the subject of U. S. letters-patent, No. 707,551, August 26, 1902, granted to G. H. Clamer. The invention discloses a new method of utilizing brass-scrap and other waste materials carrying copper, tin and lead, and producing therefrom a merchantable bronze. The report is reserved for publication in full. The Elliott-Cresson Medal is granted to the inventor. [*Sub-Committee.*—Joseph W. Richards, Chairman ; A. E. Outerbridge, Jr., Samuel P. Sadtler.]

(No. 2303.) *Measuring Device.*—Edgar Hill, Philadelphia.

ABSTRACT.—This is a patented device (U. S. patents No. 685,455, November 12, 1901, and No. 709,600, September 23, 1902) and is intended for measuring by means of two arms or caliper legs, the distance between the points of these being indicated upon a dial by means of a hand, the motion being so greatly multiplied that the hand upon the dial will clearly indicate very small distances between the points.

One leg of the device is attached to the casing which carries the bearings for the spindles of the various gears and hands, while the other leg is attached, either permanently or by means of a drag-link, to the first gear wheel. From this gear wheel motion is transmitted through several trains to the last spindle to which is attached the rapid-movement hand ; while the slow-movement hand is attached to one of the other spindles having any desired ratio of speed.

The drag-link connection between the movable arm and the first gear wheel is for the purpose of transferring automatically the circular movement of the point of the arm into a straight line measurement.

The report recognizes the utility of the device for special purposes, such as measuring a thickness beyond an obstacle, or for finding slight differences in diameter—as where a piece is not round or tapering ; also, for the quick measurement of rough iron of miscellaneous sizes. For that and other special uses the device is admitted to be very convenient. A Certificate of Merit is awarded. [*Sub-Committee.*—Wm. H. Thorne, Chairman ; Clement Remington, John Rae.]

(No. 2259.) *A Logarithmic Three-Variable Diagram.*—Harrison Everett Ashley, New Bedford, Mass..

(An advisory report.)

(No. 2289.) *Method of Making Sub-Aqueous Foundations.*—E. Becker, Washington, D. C.

(An advisory report.)

The following reports passed first reading :

(No. 2292.) *Double Universal Joint.*—Waterbury Tool Company, Waterbury, Conn.

(No. 2297.) *Lightning Arrester.*—H. M. Shaw, New York.

(No. 2298.) *Rapid Roller-Copier.*—Yawman & Erbe Manufacturing Company, Rochester, N. Y.

(No. 2299.) *Hydro-pneumatic Ash Ejector.*—Horace See, New York.

(No. 2302.) *Concrete Pile.*—Frank Sherman, Philadelphia.

(No. 2164.) *Steam Generator.*—John C. Parker, San Francisco, Cal.
Held over until next meeting. W.

Sections.

[*Abstracts of stated meetings.*]

PHYSICAL SECTION.—*Stated Meeting*, held Thursday evening, October 1, 1903. Prof. Geo. A. Hoadley in the chair.

Dr. Paul R. Heyl, Central High School, Philadelphia, read a paper entitled "A Résumé of our Knowledge of the Physical Properties of Current bearing Matter." (An abstract of this paper has been referred for publication.)

W.

ELECTRICAL SECTION.—*Stated Meeting*, held Thursday evening, October 8, 1903. Mr. Thos. Spencer in the chair. Present, 62 members and visitors.

Mr. W. E. Harrington, General Manager Camden and Suburban Railway, presented a paper on "Rail-Bonds." The communication was an exhaustive historical review of the development of this important element in the operation of the electric railway, and was profusely illustrated by specimens of these devices. The subject was freely discussed. The thanks of the meeting were tendered to the speaker. (The paper will appear in the *Journal.*)

RICHARD L. BINDER,
Secretary.

CHEMICAL SECTION.—*Stated Meeting*, held Thursday evening, October 15, 1903. Dr. Robert H. Bradbury in the chair. Present, 36 members and visitors.

The following communications were presented:

"The Estimation of Commercial Cutch," by Mr. W. E. Ridenour.

"The Determination of Citral in Essential Oils," by Mr. S. S. Sadtler.

Both papers were freely discussed.

Dr. Henry Leffmann made some informal remarks on the subject of preservatives in food products. He called attention to the interesting observation, recently made, that minute quantities of salicylic acid occur naturally in certain fruits, berries and vegetables; and that the finding of traces of this substance in food preparations would, therefore, not necessarily imply that it had been added as a preservative.

Stated Meeting, held Thursday, November 5, 1903. Dr. Harry F. Keller in the chair.

Dr. Robert H. Bradbury read a paper on "Fermentation without Yeast Cells." This was an elaborate historical sketch of the subject of fermentation, describing more especially the recent researches of Dr. Buchner.

The thanks of the meeting were presented to Dr. Bradbury for his admirable résumé of the history of this important theme.

Dr. Wahl gave a brief account of a process for utilizing waste metals, recently devised and put in operation by Mr. G. H. Clamer, a member of the Section, and exhibited a number of specimens to illustrate the application of the process.

W. E. RIDENOUR,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday evening, October 22, 1903. Mr. James Christie in the chair.

The paper of the evening was read by Mr. Luther D. Lovekin, Engineer of the New York Shipbuilding Company, Camden, N. J., describing "A New System of Expanding and Flanging Machinery and Tools."

Mr. Lovekin has devised and perfected a new line of tools and machines for this work, with which he is able to perform all kinds of expanding and flanging for boiler tubes, steam-piping—in short, all classes of iron, steel or copper piping—from the smallest to the largest sizes.

Mr. Lovekin illustrated his paper by showing a full-size machine in operation, by the exhibition of work done, showing the wide scope of the invention, and by a number of lantern slides.

The subject was freely discussed.

The speaker was voted the thanks of the meeting. (The paper will appear in the *Journal.*)

D. EPPELSHEIMER, JR.,
Secretary.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday evening, October 29, 1903. Dr. Henry Leffmann in the chair. Present, 53 members and visitors.

Mr. John Carbutt, member of the Section, presented a communication on "Improved Methods of Producing Color-Values for Monochrome and Three-Color Printing."

This paper was liberally illustrated by samples of three-color prints and lantern photographs, showing what had been accomplished in the art of making photographic plates color-sensitive.

In the discussion which followed, Mr. L. E. Levy congratulated Mr. Carbutt on the success he had attained in making photographic plates sensitive to red and green.

The second communication of the evening was a paper entitled "Upon Changing Photographic Plates from the Developing to the Fixing Bath without Recourse to the Dark Room," by Mr. Arthur W. McCurdy, of Toronto, Canada. (Read by Mr. U. C. Wanner.)

Mr. Wanner in the discussion of the paper announced that he had experimentally verified the correctness of Mr. McCurdy's statements. He exhibited a number of negatives that had been developed in the dark room and subsequently "fixed" in daylight. One negative, which had been developed in the usual way and had subsequently been exposed to daylight for two days, was "fixed" by Mr. Wanner in the presence of the members.

The subject was further discussed by Messrs. Levy, John Carbutt, Samuel Sartain, Dr. Henry Leffmann, and M. I. Wilbert.

M. I. WILBERT,
Secretary.

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